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D3.1 Toolkit

Work-Based Learning Modules | CBF Toolkit

Promoting Sustainable Furniture Production in the Western Balkan Through Strengthening the Linkages between Business Sector and VET Provider

ERASMUS-EDU-2024-CB-VET
Project Nr: 101183370

Version	**Date**
2.0	**26th of June, 2026**

This module was developed with the support of the Erasmus+ program of the European Union. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors.

Introduction

This Toolkit has been developed to support the transition of the furniture sector towards more sustainable and circular practices by strengthening cooperation between vocational education and training (VET) providers and small and medium-sized enterprises (SMEs). It provides a structured, practice-oriented framework that enables learners and professionals to apply circular economy principles in real workplace situations.

The Toolkit is organised into **three clearly defined and complementary modules**:

- **Module I: Circular Design Thinking in Furniture Production**
  focuses on the role of design in enabling circularity, introducing principles such as durability, modularity, repairability, eco-design, and design for disassembly.
- **Module II: Sustainable Furniture Production & Product Life Cycle Assessment (LCA)**
  addresses environmental performance across the product life cycle, including material selection, certification, simplified LCA, carbon footprinting, and waste reduction in production.
- **Module III: Circular Optimisation and Business Models**
  focuses on improving resource efficiency and implementing circular business approaches such as refurbishment, take-back systems, and product-service models.

Together, these three modules provide a **coherent learning pathway**—from design (Module I), through production and environmental assessment (Module II), to optimisation and business implementation (Module III).

A central principle of the Toolkit is that most environmental impacts are determined at the design stage, which is why emphasis is placed on strategies that extend product lifetime and retain value, such as maintenance, repair, reuse, and refurbishment.

The Toolkit is delivered through a **work-based learning (WBL) approach**, combining short theoretical inputs with hands-on activities using real products and production situations. This ensures that knowledge is translated into practical skills directly applicable in SMEs.

Aligned with European sustainability frameworks and market requirements, the Toolkit ultimately aims to strengthen circular competencies, improve competitiveness, and support the development of more sustainable furniture products and production systems in Western Balkan.

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Module I

Circular Design Thinking in Furniture Production

Item	Description
Document type	CBF Toolkit — Work-Based Learning Module
Module	Module I
Title	Circular Design Thinking in Furniture Production
Programme	Erasmus+ CB-VET
Project	SUSFUR — Promoting Sustainable Furniture Production in the Western Balkan Through Strengthening the Linkages between Business Sector and VET Provider
Project number	101183370
Sector	Furniture manufacturing — circular economy
Main contributors	UL & ECREC , with inputs from project partners
Status	Complete draft for partner review

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1. Module overview

1.1. Learning context and purpose

This module introduces **circular economy principles through design-led thinking** applied to furniture product development, focusing on how early design decisions influence material efficiency, product lifetime, and end-of-life outcomes. The learning rationale reflects the shift away from linear "take–make–dispose" patterns toward circular systems that **keep products and materials in use longer** and reduce dependence on virgin resource extraction. This is especially relevant for the furniture sector because a substantial share of furniture waste is still **incinerated or landfilled**, indicating strong potential for higher-value circular strategies such as maintenance, repair, reuse, and refurbishment. The module supports practical, workplace-oriented learning aligned with EU sustainability approaches, where evidence and procurement guidance highlight the importance of **materials or components** as key environmental hotspots and emphasise **durability, repairability, disassembly, and restrictions on substances of concern**. [eu-ecolabel.de], [eur-lex.europa.eu] [eeb.org], [ikea.com] [milgro.eu], [theseus.fi] [iba.online], [eeb.org]

1.2. Target audience

This module is designed for **VET learners and early-career professionals** preparing for roles in furniture design, product development, production planning, and quality/sustainability functions within furniture SMEs. It also supports **VET trainers, WBL coordinators, and workplace mentors** who need a structured framework to connect classroom learning with company practice.

1.3. Delivery format (Work-Based Learning orientation)

The module is intended for **work-based learning (WBL)** delivery, combining focused theory inputs with hands-on tasks that can be completed using real products, drawings, bills of materials, and workshop observations from host SMEs. Activities guide learners to translate circular economy principles into **concrete design and production decisions**, including modularity, joining/fastening choices, component separation, and service or repair planning.

1.4. Scope, content focus and duration

The module focuses on the **core essentials** of the five Module I topics, ensuring learners can apply circular design thinking in practice: **Foundations of Circular Economy in the Furniture Sector** (closed loops, value retention, linear vs circular).

1. **Principles of Circular Design** (durability, modularity, repairability, adaptability).
2. **Eco-design strategies from concept to prototype** (simple decision frameworks and tools suitable for SMEs).
3. **Design for Disassembly and end-of-life planning** (joinery/fastenings, mapping components to reuse/refurbish/remanufacture/recycle).
4. **User-centred circular design** (balancing aesthetics/function with circular requirements and market expectations).

1.5. Duration and two-day timetable

Total duration: 2 training days, 3–4 school hours per day (total 6–8 school hours). Recommended sequencing (compact delivery):

Day 1 (3–4 school hours): Circular economy foundations → circular design principles

- Short input: Linear vs circular furniture systems, closed loops and value retention.
- Guided discussion: why furniture impacts are driven by materials/components; why extending use matters.
- Practical task (in-class or WBL-ready): rapid assessment of one product (e.g., chair/table/cabinet) against durability, modularity, repairability and propose 2–3 improvements.

Day 2: Eco-design choices → disassembly & end-of-life → user-centred trade-offs

- Short input: eco-design decision logic (compare options; avoid substances of concern; consider VOC/formaldehyde and materials).
- Short input: **Design for disassembly** and end-of-life pathway planning (reuse, refurbish, remanufacture, recycle).
- Practical task: map components and fasteners for one product and propose **DfD improvements** plus a simple end-of-life plan.
- Wrap-up: brief **user-centred circular design** discussion (maintain aesthetics/function while improving circularity).

This two-day structure ensures the overview includes a clear duration and keeps the content aligned with the module topic sequence while remaining feasible for a short format.

1.6. Prerequisites

Learners should have:

- Basic familiarity with common furniture materials and processes (wood, wood based materials, and other materials use in furniture production e.g. metals, textiles, finishing, assembly.
- Ability to interpret simple product information (sketches, basic drawings, or specification sheets) to support design analysis tasks.

No prior specialist knowledge of circular economy is required; foundational concepts are introduced in Topic 1 and applied across the programme.

1.7. Expected learning outputs (evidence of competence)

By the end of the module, learners should produce compact, workplace-relevant outputs such as:

- A short linear-to-circular comparison for a furniture product or process.
- A circular redesign proposal (2–3 improvements) justified with reference to material-driven impacts and circular design principles.
- A basic design-for-disassembly and end-of-life plan mapping key components to reuse, refurbishment, remanufacturing, recycling pathways.

2. Learning outcomes

They align with the progression of Module I topics—from circular economy foundations through circular design principles, eco-design methods, design for disassembly, and user-centred circular design.

LO1 — Explain circular economy principles in furniture
By the end of this module, learners will be able to EXPLAIN the core principles of the circular economy in the furniture sector, given a short company/product scenario, by accurately defining circularity and identifying at least three circular strategies (e.g., maintenance, repair, reuse, refurbishment) relevant to the case.

LO2 — Compare linear and circular production models
By the end of this module, learners will be able to COMPARE linear and circular furniture production models, given a process map or product life-cycle description, by identifying at least five differences in resource use, waste generation, and value retention and summarising the implications for SME operations.

LO3 — Apply circular design principles to improve a furniture product
By the end of this module, learners will be able to APPLY circular design principles (durability, modularity, repairability, adaptability), given an existing furniture design or specification sheet, by proposing a minimum of three design modifications and justifying each modification with a clear circular benefit (extended lifetime, easier repair, component reuse, etc.).

LO4 — Use an eco-design decision framework from concept to prototype
By the end of this module, learners will be able to USE an eco-design decision framework, given two alternative design/material options for a furniture concept, by selecting the preferred option and providing a documented rationale that addresses at least four sustainability criteria (e.g., material impacts, hazardous substances, durability, end-of-life options).

LO5 — Design for disassembly and end-of-life planning
By the end of this module, learners will be able to DESIGN a basic design-for-disassembly (DfD) and end-of-life plan, given a furniture bill of materials and joining/fastening choices, by mapping at least 80% of components (by count) to a realistic pathway (reuse, refurbishment, remanufacturing, recycling) and specifying at least two joinery/fastening improvements that increase disassembly efficiency.

LO6 — Evaluate circularity while balancing user needs (aesthetics/function)
By the end of this module, learners will be able to EVALUATE the circular performance of a furniture product while considering user requirements, given a user brief and a product example, by scoring the design against a set of circular and user-centred criteria and producing a short improvement proposal that maintains function and aesthetics while increasing circularity.

3. WBL context and sector relevance

3.1. Why this module is workplace-relevant for furniture SMEs

Furniture SMEs operate in a sector where **resource use, material selection, and product design decisions** strongly shape environmental impact and cost performance across the product life cycle. In EU evidence used to inform procurement guidance, the **dominant share (often 80–90%) of environmental impacts** for furniture is linked to **materials and components**, meaning that "circular design thinking" is not an abstract concept but a direct lever for improving sustainability and competitiveness. At the same time, the sector faces a persistent end-of-life challenge: EU-level studies report that large volumes of furniture waste are generated annually and that a high share is still **incinerated or landfilled**, while **reuse and higher-value loops remain limited**, leaving significant unrealised value in products and materials. For SMEs, this creates a practical business case for circular approaches that prioritise **value retention** (maintenance, repair, reuse, refurbishment, remanufacturing) before recycling, aligning with widely used circular economy frameworks that emphasise keeping products and materials in circulation rather than treating them as waste. [iba.online], [eeb.org] [iba.online] [milgro.eu], [theseus.fi] [ikea.com], [eeb.org], [milgro.eu]

3.2. How circular design thinking connects to everyday SME workflows

Module I links directly to common furniture SME workplace practices, especially in the stages where decisions are made quickly and constraints are real (price pressure, limited supplier options, short lead times, small batches). The module is structured to help learners recognise where "circularity" can be embedded into routine decisions across design and production. Key workplace touchpoints include:

- **Product brief and concept development**
  In SMEs, design briefs typically balance aesthetics, functionality, cost, manufacturability, and delivery deadlines. Module I adds explicit circular criteria—durability, repairability, modularity, and end-of-life planning—so learners can translate circular goals into design requirements (e.g., "replaceable upholstery", "standardised fittings", "documented material composition"). This matches the expectation that circularity is enabled by design-led thinking and practical decision frameworks rather than end-of-life fixes.

- **Material and component selection (procurement + design integration)** Furniture SMEs routinely choose between solid wood, wood-based panels, metals, plastics, textiles, finishes, adhesives, and hardware—often based on availability and price. EU procurement guidance emphasises that material choice is central to impacts and highlights requirements such as legal sourcing of wood, restrictions on hazardous substances, and limits for emissions (e.g., VOCs/formaldehyde) relevant to indoor products. Module I prepares learners to justify material decisions using circular logic (e.g., avoid difficult-to-separate composites where not needed; prioritise materials and finishes compatible with repair/refurbishment).

- **Construction methods, joinery, and fastening choices**
  Workshop reality in SMEs often favours speed and consistency (staples, adhesives, permanent fittings). Module I explicitly links joinery/fastening decisions to **design for disassembly** and recovery pathways, helping learners evaluate how choices affect repair time, spare-part replacement, material separation, and recovery rates. This directly supports workplace outcomes such as fewer returns, easier warranty repairs, lower refurbishment cost, and improved end-of-life handling.

- **Finishing and chemical use (quality + compliance + indoor air quality)** SMEs frequently work with coatings, varnishes, adhesives, and upholstery materials. EU GPP criteria highlight the relevance of chemical hazard restrictions and emission limits (VOCs and formaldehyde), connecting sustainability with product quality, worker safety, and indoor air quality. Module I supports learners in spotting circular design trade-offs (e.g., choosing finishes that allow refinishing; avoiding substances that prevent reuse or safe recycling) and documenting decisions in a way that supports procurement and customer trust.

- **Service, repair, and warranty practice**
  Even SMEs that do not market “circular products” often handle repairs, spare parts, and customer complaints. Circular design principles reduce service burden by enabling faster component replacement and easier maintenance, and procurement guidance explicitly rewards durability, repairability, disassembly, and warranties. Module I therefore links design decisions to measurable operational benefits: reduced downtime, lower labour hours in repair, and improved customer satisfaction.

3.3. Sector relevance: market access and procurement readiness

For many furniture SMEs, especially those supplying B2B markets (offices, hospitality, education, public buildings), winning contracts increasingly depends on demonstrating sustainability performance and circular features. The EU’s Green Public Procurement (GPP) criteria for furniture provide practical, contract-ready requirements and award criteria covering: legal wood sourcing, limits on hazardous substances, VOC/formaldehyde emissions, durability, repairability, disassembly, and spare-part availability. By building competence in these areas, Module I helps learners and SMEs align product design and documentation with procurement expectations—turning circular design into a competitive advantage rather than an added burden. In parallel, the EU Ecolabel framework reinforces the life-cycle approach by awarding labels to products with reduced environmental impact across the full life cycle, and the EU has maintained continuity of furniture-related ecolabel criteria by extending validity timelines (supporting market stability for sustainability claims). While Module I does not require learners to certify products, it builds the foundational design thinking and evidence mindset needed to work toward such schemes.

3.4. What “Work-Based Learning” looks like in this module (SME-integrated practice)

The project methodology requires that modules clearly connect to workplace practice and include WBL-relevant activities and outputs. In this module, WBL is implemented through short, workplace-realistic tasks that can be completed using actual SME products, drawings, and production observations, even within a compact two-day delivery. Typical WBL learning evidence includes:

- **Product circularity “quick scan” in a real workshop context**: learners select one product currently produced (or commonly repaired) and identify circular improvement opportunities (durability, modularity, repair access, spare parts, disassembly).
- **Joinery and fastening review**: learners document the key joining methods used and evaluate how these choices affect repair time, disassembly, and component separation.
- **End-of-life pathway mapping**: learners produce a simple component map (e.g., wood/panel parts, metal fittings, textiles/foam, plastics) and assign realistic pathways: reuse/refurbish/remanufacture/recycle, highlighting barriers such as mixed materials or permanent bonding.
- **Eco-design decision justification**: learners compare two design options (e.g., different panel types, finishes, or fastening methods) and justify a choice using criteria linked to material impacts, hazardous substances, durability, and end-of-life feasibility.

These outputs fit the methodology requirement that learners produce clear deliverables and that the module maintains strong workplace relevance.

3.5. Role of workplace mentors and VET trainers (bridging learning and production reality)

Because furniture SMEs vary widely in product range, machinery, and supplier networks, the role of trainers and workplace mentors is to help learners interpret circular principles within local constraints and identify “high-impact, feasible” improvements. Mentors can support by providing access to a product sample, a bill of materials, typical repair cases, and a short walk-through of assembly and finishing steps—enabling learners to ground circular thinking in real workflows. This supports the module objective that VET providers contribute to capacity-building for circular economy adoption across the sector, using WBL tasks that mirror workplace decision-making.

3.6. Relevance for SMEs in the Western Balkans (practical transition needs)

The module is designed for SME realities where time and investment capacity can be limited, so it emphasises improvements that can be implemented progressively: design changes enabling easier repair, standardised replaceable parts, improved documentation, and disassembly-friendly construction. This aligns with sector studies that recommend step-by-step transition approaches and highlight the need for skills and competence development to support circular business practices in furniture. By focusing on design-stage decisions—where many impacts and costs are “locked in”—Module I provides immediate relevance to SMEs seeking to reduce waste, improve quality, and meet evolving buyer requirements without requiring major capital investment.

4. Modul I. Foundations of Circular Economy in the Furniture Sector

4.1. Foundations of Circular Economy in the Furniture Sector

This unit introduces the **core concepts of the circular economy** as applied to furniture: **closed-loop systems**, **value retention**, and the practical differences between **linear** and **circular** production models. It is designed to help learners connect these concepts to real SME practice and to the work-based learning (WBL) approach required in the toolkit methodology.

4.1.1. Key terms and why the furniture sector matters for circularity

Circular economy (CE) is a system-level approach aiming to redesign how we create and use products so that we can **reduce waste**, **keep materials in use**, and **reduce pressure on natural systems**. The European Environment Agency (EEA) explains that the prevailing linear model—short use followed by disposal—creates ongoing waste and sustained demand for virgin raw materials, making circular approaches essential for sustainability. Furniture is a high-priority sector for CE because large volumes are discarded every year and much of it still ends up in **landfill or incineration**, while higher-value options (reuse, refurbishment, remanufacturing) remain underused. Sector studies describe furniture waste as a meaningful share of municipal waste streams and report limited reuse activity, indicating substantial unrealised value and opportunity.

Info: Why "circular furniture" is not only recycling.

In furniture, circularity is best achieved by keeping the product functioning for longer (maintenance, repair, reuse, refurbishment) and only using recycling as a later option when higher-value loops are no longer feasible.

4.1.2. The core principles of the circular economy (applied to furniture)

A widely used CE framing sets out three principles: **(1) eliminate waste and pollution by design**, **(2) circulate products and materials at their highest value**, and **(3) regenerate natural systems**. For furniture companies, these principles translate into practical design and production priorities: reducing material waste, choosing safer and more compatible materials, extending product lifetime through repairability, and planning for end-of-life recovery.

The EU's Green Public Procurement (GPP) guidance for furniture highlights that a dominant share of furniture impacts is linked to **materials/components**, and therefore decisions about material choice, coatings, and construction methods are central to environmental performance. This is why "circular design thinking" starts in the **design brief**, not at the waste stage: once material combinations, adhesives, and joinery choices are locked in, repairability and recyclability can become technically or economically difficult.

Key concept: Circular furniture design aims to keep products and materials in circulation for as long as possible through durability, repair, reuse, refurbishment, remanufacturing, and finally recycling—reducing waste and virgin material demand.

4.1.3. Linear vs circular production models: practical differences for SMEs

A) The linear model ("take–make–dispose")

In a linear system, resources are extracted, transformed into products, sold, used, and then discarded, leading to continuous waste generation and continued extraction of virgin materials. EEA emphasises that this model drives unsustainable consumption patterns because materials are not reused or recycled at the scale required for sustainability.

B) The circular model (keeping products/materials in loops)

In a circular system, products are designed and managed so they can remain in use longer and re-enter value-preserving loops such as repair, reuse, and refurbishment, with recycling as a later pathway. For SMEs, the key operational difference is that circularity requires **planning** for multiple life cycles (service, spare parts, disassembly) rather than optimising only for first sale and fast production.

Aspect	Linear furniture model	Circular furniture model
Resource input	Mostly virgin materials	Higher share of renewable/recycled inputs; reuse components where feasible
Design focus	Aesthetics, cost, speed-to-market	Aesthetics + durability + repair + disassembly + materials health
Value creation	Value captured mainly at first sale	Value captured across multiple cycles (repair, resale, refurbishment, remanufacturing)
End-of-life	Waste; limited recovery	Planned recovery routes: reuse → refurbish → remanufacture → recycle
Waste	Treated as externality	Designed out; minimized across lifecycle

Table 1 — *Linear vs circular furniture models (SME perspective)*

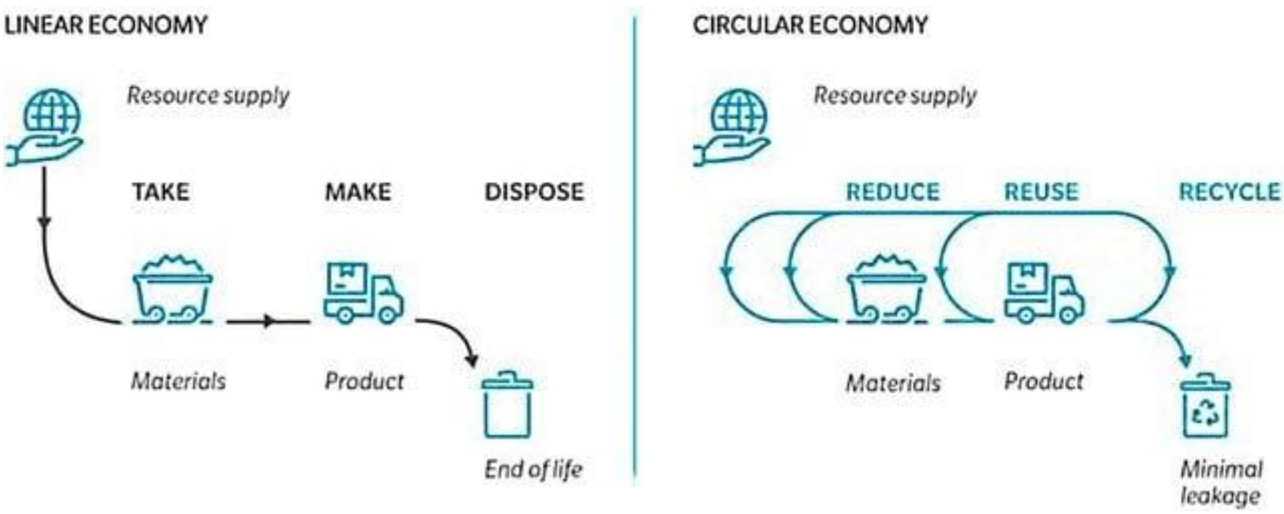

Figure 1: *Linear economy vs. circular economy* (Source: Matheri et al. 2024)

Tip: Start by identifying one product line where repairs are common and redesign two weak points (e.g., replace glued joints with reversible fasteners; standardise a replaceable part). These small changes can unlock reuse and reduce waste without major investment.

4.1.4. Closed-loop systems in furniture: what "loops" look like

A **closed-loop system** aims to keep products and materials circulating so that outputs from one stage become inputs for another stage, reducing the need for virgin resources and avoiding waste. In furniture practice, "loops" are typically implemented through maintenance and service, repair, reuse, refurbishment, remanufacturing (where applicable), and recycling.

A practical furniture-specific loop model (from the FURN360 sector report) identifies six key cycles that increase circularity: **Maintain, Repair, Reuse, Refurbish, Re-purpose, Recycle**. These cycles highlight a crucial idea: the most circular option is often the one that keeps the product as the same product (e.g., "a chair remains a chair") through maintenance or repair or reuse, because this preserves more embedded value than material recycling.

4.1.5. Example (workplace-relevant) — How a chair can stay in the loop

- **Maintain:** tightening fasteners, replacing felt glides, surface care.
- **Repair:** replacing a broken component or upholstery without scrapping the whole chair.
- **Reuse:** resale or redeployment within an organisation (B2B reuse).
- **Refurbish:** re-upholstery, refinishing, or updating to extend "fashion life."
- **Recycle:** only when other options are not viable, and only if materials can be separated effectively.

4.1.6. Value retention: why circularity prioritises the "top loops"

Value retention means keeping as much of the product's embedded value as possible—materials, manufacturing energy, labour, and design—by maintaining the product in use rather than destroying it for low-grade material recovery. Sector evidence shows that furniture waste treatment is still dominated by landfill and incineration in many contexts, which represents a loss of both material value and the value created through manufacturing and design.
EU GPP furniture guidance also notes that end-of-life outcomes depend heavily on the ability to **separate components**, and that recovery can be complicated by mixed materials and design choices that prevent disassembly.
Therefore, value retention is strongly linked to design decisions such as reversible fasteners, modular components, accessible repair points, and material transparency (so parts can be safely reused or recycled).

Key concept: The earlier the loop (maintenance/repair/reuse), the higher the value retained and the lower the need for new materials—making these strategies central to circular furniture design.

4.1.7. Drivers and benefits for furniture SMEs (Western Balkans focus)

The drivers for circular economy adoption in furniture SMEs typically combine **economic pressure**, **market expectations**, and **policy/procurement signals**. Sector reports describe increasing cost pressures (materials, labour, energy) and the need for new practices to improve sustainability and competitiveness—conditions that are highly relevant to SME environments.

Key drivers (typical for SMEs supplying EU-linked markets)

- **Cost resilience:** reducing material losses and dependence on virgin inputs through better yield and reuse loops.
- **Access to contracts:** public and B2B buyers increasingly use sustainability and circular requirements, and the EU GPP furniture criteria provide ready-made specifications and award criteria (durability, repairability, disassembly, emissions limits).
- **Risk management:** avoiding substances of concern and designing for safer material cycles, which supports compliance and future-proofing.

Benefits SMEs can expect (practical, operational, and market-oriented)

- **Reduced waste and rework:** designs that are easier to assemble, repair, and refurbish can reduce internal scrap and customer returns.
- **New service revenues:** repair/refurbishment and take-back services can create additional value streams and strengthen customer relationships.
- **Improved competitiveness:** demonstrating durability, low emissions, and circular features aligns with procurement criteria and sustainability labels.

Note on EU Ecolabel continuity (market relevance): The EU has maintained continuity for furniture ecolabel criteria by extending validity timelines, reflecting ongoing relevance of life-cycle-based environmental requirements in the market context.

4.1.8. The role of VET providers in building circular capacity (WBL relevance)

This unit is part of a module explicitly designed to build circular economy skills through **work-based learning (WBL)**, meaning learners should practise applying concepts to real products and workplace situations. The toolkit learning objectives specifically require that learners recognise the role of VET providers in developing circular capacities across the furniture sector.

In practice, VET providers strengthen circular capacity by:

- teaching circular economy concepts with **sector-specific examples** (furniture loops and design decisions), not generic theory;
- training learners to use procurement- and industry-relevant criteria (durability, repairability, disassembly, emissions) that appear in EU guidance;
- embedding learning into WBL tasks (product audits, redesign proposals, end-of-life mapping), matching the required module structure and activity approach.

Tip: Ask the host SME to provide one product sample (or drawing + bill of materials). Learners can complete a "linear-to-circular" mapping, identify 3 circular improvements, and propose an end-of-life pathway plan aligned with the six loops (maintain–repair–reuse–refurbish–repurpose–recycle).

4.1.9. Summary (takeaways)

- Circular economy in furniture is a design- and system-led approach aimed at keeping products/materials in use longer and reducing waste and virgin resource demand
- The furniture sector has major circular potential because large volumes are discarded and high shares still go to landfill/incineration, while higher-value loops remain limited.
- EU guidance highlights that materials/components drive much of furniture's environmental impact and stresses durability, repairability, disassembly, and emissions restrictions as practical circular levers.

- VET providers play a key role by translating CE concepts into WBL tasks and workplace decision-making skills.

4.1.10. Quick knowledge check (5–10 minutes)

- **Define** circular economy in one sentence for a furniture SME and name **two** CE principles.
- **Compare** linear vs circular furniture models and list **three** differences (resources, waste, value retention).
- **Identify** the six furniture loops (maintain, repair, reuse, refurbish, re-purpose, recycle) and explain which ones retain the most value.
- **Explain** why material/component choices are critical environmental hotspots in furniture.
- **Describe** one concrete action a VET provider can take to build circular capacity through WBL in a furniture SME.

4.2. Principles of Circular Design: Durability, Modularity, and Repairability

This unit explains how to embed circularity into the design phase of furniture products through four core design principles—durability, modularity, repairability, and adaptability—and by making informed choices about materials, construction, and disassembly.
It connects these principles to practical SME realities and to EU guidance that increasingly emphasises durability, repairability, availability of spare parts, and ease of disassembly as key performance expectations for furniture products.

4.2.1. Circular design thinking in furniture: what it means in practice

Circular design in furniture is the discipline of shaping a product so it can stay in use longer, be maintained and repaired efficiently, and be recovered at end-of-life through planned pathways rather than disposal. This design approach is highly relevant because the circular economy requires moving away from a linear system where products are used briefly and then discarded, toward systems that keep products and materials circulating longer.
In furniture, circular design is rarely a single feature; it is a combination of design decisions that work together, typically including:

- **Durability** (long technical life and long "aesthetic" life)
- **Modularity** (replaceable and upgradable modules/components)
- **Repairability** (fast, low-cost repairs and spare parts)
- **Adaptability** (the product can be reconfigured for new use cases)
- **Design for disassembly** (DfD) as an enabler for repair, reuse, and recycling

Key concept: Most circular performance is determined at the design stage, because materials, coatings, adhesives, and joining methods can either enable repair/disassembly or make them technically difficult and expensive.

4.2.2. Durability: designing furniture to last (physically and emotionally)

Durability is the ability of a product to perform its function safely and acceptably over a long period. In circular terms, durability is valuable because it reduces the frequency of replacement and therefore reduces demand for new materials and manufacturing impacts.

EU furniture procurement guidance makes this link explicit by recommending the procurement of **durable, fit-for-use furniture** that complies with relevant standards and is supported by warranties—because premature end-of-life is a major source of wasted materials and avoidable impact. Sector evidence also identifies "lower quality materials and poor design" as a barrier to circularity because weak construction limits the potential for a successful second life (repair, resale, refurbishment).

Practical durability design strategies:

- **Structure and load paths:** Use construction that maintains strength over time (appropriate thickness, reinforcement where needed, robust joints).
- **Surface and finish durability:** Choose finishes that resist wear but can also be refinished (e.g., sandable coatings rather than irreversible surface systems where appropriate).
- **"Aesthetic durability":** Use timeless forms and replaceable visible parts (e.g., upholstery covers) to extend fashion life—refurbishment is explicitly highlighted as a key furniture loop (e.g., re-upholstery, refinishing).
- **Warranty/service design:** Durability is reinforced when products are designed so warranty repairs are feasible and quick; procurement criteria reward warranty coverage and repairable designs.

Tip: In SMEs, product returns and after-sales repairs consume skilled labour. Designing for durable joints and easy replacement of high-failure parts reduces service hours and improves profitability while supporting circular goals.

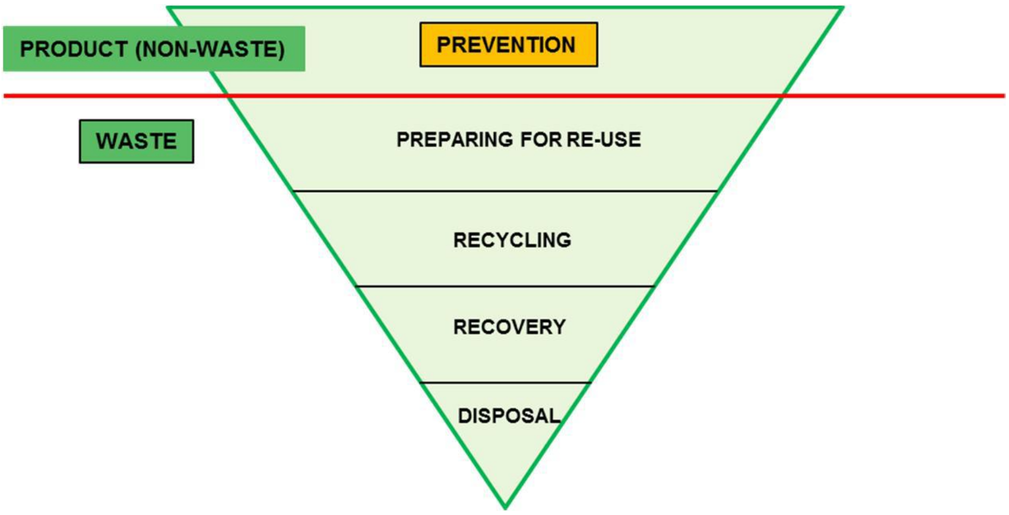

Figure 2: *Principles of circular design are a key to prevent waste*

4.2.3. Modularity: keeping products relevant through replaceable and upgradable parts

Modularity means designing a product as a set of components (modules) that can be replaced, upgraded, or reconfigured without scrapping the whole product. This supports longer use and enables refurbishment and remanufacturing practices highlighted in furniture sector circularity work.

In furniture, modularity is particularly powerful because many products fail (or become unwanted) due to a limited number of components: upholstery, hardware, moving parts, surfaces, feet/glides, hinges, or damaged subframes. Enabling easy replacement can keep the whole product in use.

Common modular design approaches in furniture

- **Replaceable wear layers:** removable upholstery covers, replaceable pads, replaceable surface laminates or top layers where feasible.

- **Standardised interfaces:** consistent hole patterns, standard fasteners, standard bracket geometries that allow part substitution.
- **"Upgrade modules":** add-on accessories or subassemblies (e.g., armrests, cable management, storage units) to adapt a product to new needs rather than replacing it.
- **Separable subassemblies:** a base/frame that can be retained while surfaces or functional parts are changed (supports refurbishment and remanufacturing loops).

Key concept: Modular furniture anticipates change (wear, style updates, new functions) and makes change inexpensive and fast, enabling reuse and refurbishment rather than disposal.

4.2.4. Repairability: design so repairs are fast, safe, and affordable

Repairability is the ease with which a product can be restored to function using available skills, tools, and parts. In circular terms, repairability enables high-value loops like **repair and reuse**, which preserve more value than recycling.

EU procurement guidance for furniture places strong emphasis on purchasing items that are **easy to disassemble, repairable, and recyclable**, and it also highlights the importance of **spare parts** and warranty/service provisions. Sector studies also identify "availability of spares" and high repair or refurbishment costs as barriers, implying that design choices which reduce repair time and increase spare-part availability can directly enable circularity.

Figure 3. *Local training in Slovenia;* Photograph by UL (2026)

Repairability design features (practical checklist)

- **Access:** Provide tool access to failure points (don't hide critical fasteners behind glued panels).
- **Reversible joining:** Prefer mechanical fasteners and joinery that can be opened and re-closed without damage (supports both repair and disassembly).
- **Part identification:** Mark or document part codes, materials, and hardware types so replacements can be sourced accurately (supports traceability expectations in supply chains).
- **Spare parts strategy:** Design around components that can be stocked or sourced for a defined period; procurement criteria reward spare-part availability and extended warranties

Tip: If replacing a common part takes 10 minutes instead of 60, repair becomes economically realistic for SMEs—so repairability should be tested as a time-based task during prototyping.

4.2.5. Designing for disassembly (DfD): the enabler for repair, reuse, and recovery

Design for disassembly (DfD) means designing products so they can be taken apart efficiently into components and materials. This is a key bridge between the "use phase" loops (repair/refurbish) and end-of-life recovery (reuse/remanufacture/recycle).

EU GPP furniture criteria explicitly highlight that end-of-life recycling and recovery are often complicated because components are hard to separate, and therefore encourage designs that are easier to disassemble and that support material separation. Sector analysis likewise notes that weak design drivers for disassembly and repair limit circular outcomes, and that policy and market mechanisms increasingly push for better design specifications.

DfD strategies that work well for furniture SMEs

- **Minimise permanent bonding** where it blocks repair or separation (e.g., avoid unnecessary glued multi-material stacks).
- **Use standard fasteners** and reduce the number of fastener types (faster disassembly, fewer errors).
- **Separate materials by design:** make it obvious and simple to separate wood/panel parts, metals, plastics, textiles/foam.
- **Plan disassembly sequence:** ensure parts can be removed without destroying others (important for refurbishment and component harvesting).

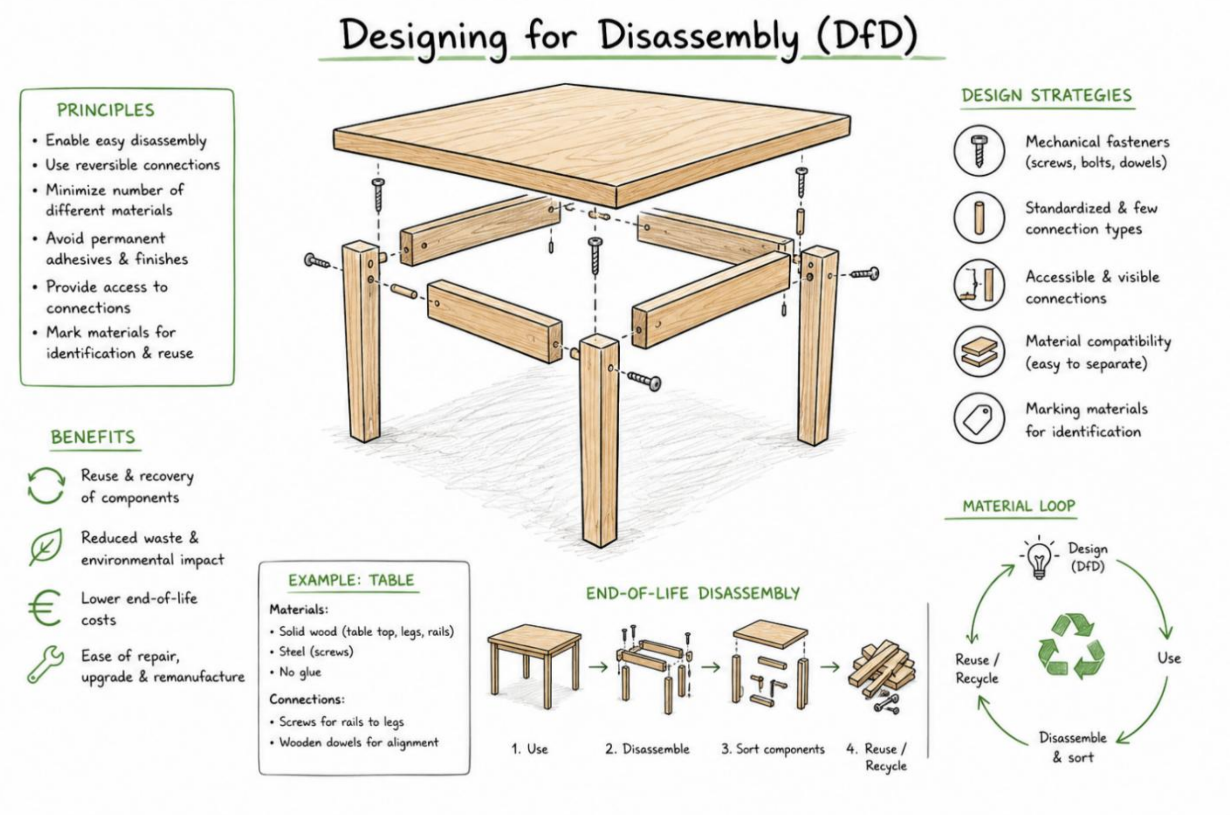

Figure 4. *Design for disassembly*

4.2.6. Material selection: how design-stage choices determine circular potential

Material selection strongly determines whether furniture can be repaired, refurbished, safely reused, or recycled. EU procurement guidance summarises evidence that the **dominant share (80–90%) of environmental impacts** is linked to materials and components, making material choice a primary circularity lever.

Circular material selection principles (furniture context)

1. **Prefer materials compatible with long life and repair.** Select materials that maintain performance

over time and can be refinished or repaired (supports durability and refurbishment loops).

2. **Avoid material combinations that prevent separation.** Mixed-material composites and permanently bonded layers can make disassembly and recycling difficult, reducing end-of-life options and making refurbishment more complex.
3. **Control substances of concern and emissions.** EU GPP furniture criteria include restrictions around substances of very high concern (SVHC) and include requirements/limits relating to VOC and formaldehyde emissions in relevant components and finishes, linking circularity to health and safe material cycling.
4. **Use recycled/renewable content where feasible without sacrificing durability** GPP guidance notes that specifying recycled materials can reduce material impacts, while still recognising that durability and recyclability matter; the best choice is often the one that balances lifetime performance and recoverability.

Key concept: A material is more circular when it can stay in use longer (durability), be safely handled (low hazardous content), and be separated and recovered at end-of-life (disassembly and recycling quality).

4.2.7. Applying the principles: a simple evaluation and improvement approach

A practical way to evaluate an existing furniture design is to review it against four questions aligned with the learning objectives (durability, modularity, repairability, and circular material choices).

Step 1 — Durability check (function + lifetime)

- What are the most common failure points (joints, surfaces, moving parts, upholstery)?
- Does the design support long use with minimal degradation (structure, finish, stability)? https://iba.online/en/newsroom/topics/public-procurement-of-office-furniture-in-europe-when-sustainability-becomes-standard-practice/

Step 2 — Modularity check (replace/upgrade or multifunctional use)

- Which parts could be made replaceable modules (covers, hardware, feet/glides, surfaces)?
- Are interfaces standardised to allow easy substitution and upgrades?

Step 3 — Repairability & DfD check (time and access)

- Can the product be opened and reassembled without damage?
- How many fastener types are used, and are they accessible?
- Are spare parts and documentation feasible (part codes, materials list)?

Step 4 — Material circularity check (health and separation)

- Are there substances/finishes that block reuse, safe refurbishment, or recycling?
- Can materials be separated into clean streams at end-of-life?

Expected output (for later use in Activities/Assessment): A short improvement proposal recommending **at least three changes** that strengthen circularity (e.g., one durability improvement, one modularity improvement, one repair/disassembly improvement) and explaining the circular benefit of each.

4.2.8. Unit summary (takeaways)

- **Durability** prevents premature end-of-life and supports reuse/refurbishment, which are higher-value loops than recycling.
- **Modularity** enables replacement and upgrades of parts most likely to wear or become outdated, extending useful life.
- **Repairability** depends on access, reversible fasteners, and spare parts—areas strongly emphasised

in EU furniture procurement guidance.

- **Design for disassembly** is essential to make repair, refurbishment, and end-of-life recovery feasible and cost-effective.
- **Material selection** is a major lever because material/component impacts dominate furniture life-cycle impacts and because hazardous substances and emissions affect safe circular flows.

4.2.9. Quick knowledge check (5–10 minutes)

1. **Explain** the difference between durability and repairability, and give one furniture example for each.
2. **Identify** two modular design strategies that could extend the life of an upholstered chair or office desk.
3. **Evaluate** one design feature that makes disassembly difficult and propose a better alternative.
4. **Describe how** material selection influences circular potential and name one risk related to emissions/substances.

4.3. Eco-Design Strategies for Furniture: From Concept to Prototype

This unit provides **practical eco-design methodologies, tools, and decision frameworks** that furniture designers, VET learners, and SMEs can apply from the earliest stages of product development—moving from concept to prototype with clear sustainability criteria. It builds on the circular economy foundation and circular design principles by showing *how to make design decisions* that reduce environmental impact across the life cycle, with particular attention to materials and components, which are often the dominant impact hotspots in furniture.

4.3.1. What eco-design means in a furniture context

Eco-design (also referred to as Design for Environment, DfE) is an approach that integrates environmental considerations into product design and development, using life-cycle thinking to avoid shifting impacts from one stage to another (e.g., reducing production impacts but increasing end-of-life impacts). In practical terms, eco-design makes it possible to evaluate environmental consequences **already in the planning and concept stages**, and to compare design variants while still keeping technical and cost constraints visible.

For furniture, this focus is critical because EU procurement guidance summarising LCA evidence highlights that the **dominant share (often 80–90%)** of environmental impacts is linked to **materials and components**, meaning eco-design must start with material and construction choices—not only with end-of-life actions. https://iba.online/en/newsroom/topics/public-procurement-of-office-furniture-in-europe-when-sustainability-becomes-standard-practice/

Info: Eco-design is not a single "green feature." It is a structured decision process that uses life-cycle thinking to reduce impacts across materials, manufacturing, distribution, use/maintenance, and end-of-life. [ibp.fraunhofer.de], [green-foru....europa.eu]

4.3.2. Key eco-design methodologies used in practice

Different eco-design methodologies exist, and SMEs typically need approaches that are **structured but lightweight**, allowing early-stage decisions without requiring a full specialist LCA every time.

A) Design for Sustainability (D4S) — step-by-step practical guidance

Design for Sustainability (D4S): A Step-by-Step Approach is designed to support designers and industry, including newcomers, and covers redesign of existing products, sustainable product innovation, and new product development with "how-to" guidance and tools. This is particularly useful in furniture SMEs because many circular improvements start with **redesigning existing products** (e.g., making parts replaceable, simplifying disassembly, improving material choices).

B) ISO 14006 — integrating eco-design into management systems

ISO 14006:2020 provides guidelines for incorporating eco-design into an environmental management system (EMS) and supports organisations in establishing and improving eco-design management practices (it is applicable across organisation types and sizes). For SMEs, the value is a repeatable process: eco-design becomes part of how products are specified and reviewed, not a one-off project.

C) Environmental Footprint / PEF (EU method) — structured life-cycle quantification

The European Commission's **Product Environmental Footprint (PEF)** method is an LCA-based framework that provides rules to quantify and communicate environmental impacts of products across the supply chain—from raw materials to waste management—using defined modelling requirements. While a full PEF study can be demanding, its logic supports SMEs through **screening and hotspot thinking**: identify the most important life-cycle stages and focus design effort where it matters most.

4.3.3. Eco-design workflow for furniture: concept → prototype (a practical roadmap)

A consistent eco-design workflow helps learners and SMEs move from ideas to decisions and tangible prototypes without losing sustainability intent.

Step 1 — Define the functional unit and design intent (concept clarity)

Start by defining what the product must do (function, load, user context, expected lifetime, service conditions). This mirrors the life-cycle logic used in LCA-based methods such as PEF, which begin with goal and scope thinking and then quantify impacts.

Practical output: a one-page concept brief including target users, use scenario, expected service life, and circular goals (repair, modularity, disassembly).

Step 2 — Identify hotspots (screening) before detailed design

Use a quick hotspot scan to ask: "Where will most impact come from—materials, coatings, transport, end-of-life?"

EU GPP furniture evidence points strongly to materials/components as dominant hotspots, so a reasonable default in furniture is to prioritise material selection, construction choices, and finishes/chemicals.

Practical output: a shortlist of 3–5 "priority decisions" (e.g., panel type, finish system, fastening approach, replaceable parts).

Step 3 — Generate alternatives (eco-design options)

Generate at least two alternative solutions for each priority decision (e.g., reversible vs permanent fastening, modular vs monolithic structure, low-emission finish vs conventional). D4S guidance emphasises redesign and new product development approaches supported by tools and worksheets, which can be applied here to structure option generation.

Step 4 — Evaluate alternatives with a decision framework

Evaluate options against sustainability criteria and technical constraints (strength, manufacturability, cost, compliance, indoor emissions). This aligns with the PEF concept of modelling flows and emissions throughout life cycle stages to understand and manage impacts.

Step 5 — Prototype with verification in mind

Prototyping should test not only form and function but also **repair time, disassembly sequence, and replaceability of modules**, because these determine whether circular design works economically in SMEs. One off eco-design approach highlights that LCA-supported processes allow product modifications to be examined early and quantified, helping teams avoid ecologically unfavourable solutions before committing fully.

4.3.4. A simple eco-design decision framework (SME-friendly)

Below is a lightweight framework you can use in concept selection and prototype review. It combines life-cycle thinking (materials → manufacturing → use/maintenance → end-of-life) with circular design requirements (durability, repairability, disassembly).

Eco-design decision matrix (use during concept selection)

For each design option, score 0–5 (0 = poor, 5= strong) and write a one-line justification.

A) Materials and components

- Renewable/recycled content potential and responsible sourcing (where relevant)
- Material efficiency (mass minimisation without over-design)
- Material separability (avoid hard-to-separate composites where not needed)

B) Chemicals and emissions (health and safe cycles)

- Coatings/adhesives aligned with lower hazard and emissions expectations (VOC/formaldehyde considerations where applicable)

C) Durability and lifetime

- Expected lifetime under use conditions; resistance to common failure modes
- “Aesthetic durability” potential (refinishable surfaces, replaceable visible elements)

D) Repairability & modularity

- Access to fasteners and failure points; time to replace key parts
- Modular replacement/upgrades possible without destroying the product

E) Disassembly & end-of-life options

- Disassembly sequence feasible; limited fastener types; reversible joints
- Clear end-of-life pathways: reuse/refurbish/remanufacture/recycle

Practical rule: If two options are similar in cost and performance, select the one with higher scores in **materials**, **repairability**, and **disassembly**, because these are repeatedly highlighted as major drivers of circular performance and procurement expectations in the furniture sector.

4.3.5. Integrating sustainability criteria into concept and prototyping

Eco-design works best when sustainability criteria are built into standard design gates (concept review, design freeze, prototype validation).

Concept stage (before detailed CAD and tooling)

At concept stage, the most important sustainability decisions are:

- **Material strategy** (what materials are used and why; how separable they are)
- **Construction logic** (modular architecture, reversible fasteners, access points for repair)
- **Finish/chemical approach** (avoid hazardous substances and support indoor air quality expectations)

Prototype stage (prove it works in real time)

During prototyping, validate circular features with measurable checks:

- **Repair test:** replace a likely-to-fail part within a defined time (e.g., 10–20 minutes) using typical workshop tools
- **Disassembly test:** separate the product into main material streams without damaging reusable parts
- **Refurbishment test:** confirm surfaces or covers can be refinished/replaced to extend aesthetic life

These tests reflect the idea that circularity must be economically feasible in SMEs (labour time and tool simplicity matter) and that end-of-life recovery depends on separability.

4.3.6. Tools and resources for eco-design in SME contexts (what is "accessible")

Eco-design does not require that every SME performs a full LCA. Practical progress can be achieved using a layered toolkit: simple checklists first, then screening footprints, then more detailed studies when needed.

A) Structured guidance and process tools

- **D4S manual**: step-by-step guidance, including redesign approaches and tools/worksheets for first-time users.
- **ISO 14006**: guidelines to embed eco-design into organisational management systems, supporting consistent practice over time.

B) Life-cycle and footprint methods (for screening and communication)

- **EU PEF method**: LCA-based rules to quantify and communicate product environmental impacts; helpful as a structure for hotspot focus and for credible claims.

C) Furniture-specific policy/procurement criteria (practical "ready-to-use" checks)

- **EU GPP Furniture Criteria** provide concrete requirements and verification approaches for materials, chemicals, emissions, durability, disassembly, repairability, and warranties—useful as a design checklist even outside procurement contexts.

Rating scale (1–5)
5 = Very good (best)
4 = Good
3 = Moderate
2 = Poor
1 = Very poor (worst)

Criteria	Weight (%)	Option A Score (1–5)	Option B Score (1–5)	Option C Score (1–5)	Weighted Score	Weighted Score	Weighted Score	Rank
Material sustainability (renewable, recycled content, responsibly sourced)	25%	4	3	5	1.00	0.75	1.25	1
Design for disassembly (ease of separating components)	20%	2	3	5	0.40	0.60	1.00	1
Recyclability / End-of-life (ability to recycle or compost)	20%	3	3	5	0.60	0.60	1.00	1
Environmental impact (LCA: carbon, water, pollution)	20%	3	3	5	0.60	0.60	1.00	1
Durability & performance (expected lifetime, strength)	10%	4	3	4	0.40	0.30	0.40	1
Cost (total life cycle cost)	5%	3	4	3	0.15	0.20	0.15	2
TOTAL	100%	–	–	3.15	3.05	4.80	BEST OPTION OPTION C	

Figure 5. *Example of decision matrix for chair*

Tip: Start with EU GPP criteria as a practical checklist, use D4S for structured redesign steps, and use PEF logic for hotspot prioritisation and transparent documentation.

4.3.7. Example: applying the framework to a furniture concept

Consider two design options for a small table:

- **Option A:** mixed-material bonded top (laminate + adhesive layers), hidden fasteners, non-replaceable feet
- **Option B:** mechanically fixed top surface, standardised fasteners, replaceable feet/glides, documented materials

Using the eco-design decision matrix, Option B will typically score higher on **separability, repairability, and disassembly**, which are directly linked to circular pathways and end-of-life feasibility in EU furniture guidance.

It also supports higher-value loops such as refurbishment (surface replacement) and reuse (simple repairs), which are explicitly highlighted as important furniture circular cycles.

Figure 6. *Example of eco design* (Ben Wilson – Chairfix – Eco-design) Credit: https://altermaker.com/eco-design-definition/

4.3.8. Unit summary (takeaways)

- Eco-design integrates life-cycle thinking into design decisions early, preventing impact shifting and enabling better environmental and cost outcomes.
- Practical eco-design methodologies for SMEs include UNEP D4S guidance, ISO 14006 for process integration, and EU PEF/Environmental Footprint methods for structured life-cycle assessment and communication.
- In furniture, materials and components are key hotspots, so eco-design should prioritise material choices, construction, finishes, and disassembly and repair planning.
- A simple decision framework (scores + justifications) allows consistent concept selection and prototype validation aligned with circular requirements (durability, repairability, modularity, disassembly).

4.3.9. Quick knowledge check (5–10 minutes)

1. **Describe** two eco-design methodologies that can guide furniture development and state what each is used for.

2. **Use** the eco-design decision matrix to compare two design options and identify which option is better and why (give three criteria).
3. **Explain** why materials are often the main hotspot in furniture and name one design decision that directly affects this hotspot.
4. **Identify** one prototype test that verifies circular performance (repair time, disassembly sequence, or refurbishment feasibility).

4.4. Design for Disassembly and End-of-Life Planning

This unit explains how to design furniture components so they can be efficiently taken apart, separated by material, and routed into reuse, refurbishment, remanufacturing, or recycling pathways at end-of-life. It links design decisions (joinery, fasteners, materials, documentation) to practical outcomes: easier repair and refurbishment, higher recovery potential, and reduced end-of-life losses caused by difficult-to-separate components.

4.4.1. Why Design for Disassembly (DfD) matters in furniture

A circular economy requires keeping products and materials in use longer and enabling high-value loops such as repair, reuse, refurbishment, and remanufacturing before recycling. In furniture, end-of-life recovery is frequently complicated because many products contain mixed materials and non-reversible connections, making separation costly and reducing the feasibility of reuse or quality recycling.

EU guidance for furniture procurement explicitly notes that end-of-life impacts vary by material composition and that recycling or energy recovery is often complicated due to **difficulties in separating components**, which is why "easy to disassemble, repairable and recyclable furniture" is emphasised. Sector reports similarly identify weak design drivers for disassembly/reassembly and repair as barriers to circularity, alongside limited take-back infrastructure and high repair/refurbishment costs.

Key concept: Design for disassembly increases the feasibility of repair, refurbishment, remanufacturing, and recycling by making it possible to access, separate, and recover components without destroying them. [link.springer.com], [research.cbs.dk]

Figure 7. *Local training in Slovenia. Sourcing for new life of furniture,* Photograph by UL (2026).

4.4.2. What DfD means (furniture-specific definition)

Design for Disassembly (DfD) means designing furniture so that it can be taken apart efficiently—ideally with commonly available tools—allowing components to be repaired, replaced, reused, or separated into clean material streams for recycling. DfD is not only an "end-of-life" concept; it also supports **service and repair** during the use phase by enabling access to wear components (e.g., glides, hinges, upholstery, gas lifts) and by allowing reassembly without loss of function.

A furniture-focused case study literature also frames DfD as an effective strategy to increase the possibilities for **repairing, remanufacturing, and recycling**, thereby keeping products in circulation for longer.

4.4.3. The "DfD ladder": prioritising value retention before recycling

In circular furniture systems, the goal is to keep a product (or its modules) functioning in the same form for as long as possible through maintenance, repair, reuse, and refurbishment; only later should recycling occur. DfD directly supports these higher-value loops because disassembly enables non-destructive replacement of modules and components, and it makes refurbishment (e.g., re-upholstery, refinishing) more economically viable.

Sector research identifies six practical furniture loops—maintain, repair, reuse, refurbish, repurpose, recycle—illustrating that "a chair remains a chair" is the highest-value outcome and that refurbishment can extend "fashion/service life." EU procurement guidance complements this by emphasising durability and repairability as crucial for extending the use phase and by highlighting disassembly to support repair and material separation.

4.4.4. Joinery and fasteners: what makes furniture "disassemblable"

Furniture disassembly performance depends heavily on how parts are connected. A comprehensive review of furniture joinery for DfD classifies joinery solutions into **non-disassemblable**, **conditionally disassemblable**, and **fully disassemblable** categories, and concludes that only fully disassemblable solutions align reliably with DfD. The same review evaluates joinery solutions including traditional joints, dowel/biscuit, nailed/stapled, directly screwed, snap-on, expandable, and cam/bolt fasteners, linking joinery choice to the feasibility and cost of disassembly.

Non-disassemblable and "conditionally disassemblable" connections (avoid or limit)

Connections that require destruction to separate parts reduce both repair potential and end-of-life recovery. Adhesive-based joints and hybrid joints that combine glue with other fixings commonly fall into the non-disassemblable category and can make disassembly destructive.

Conditionally disassemblable joints might technically come apart, but the disassembly is too time-consuming, damages parts, or leads to reduced performance after reassembly—making them economically unattractive for SMEs.

Fully disassemblable connections (prefer)

The joinery review postulates a preference for **expandable fasteners** and **cam/bolt fasteners** as strong candidates for DfD because they support repeated assembly/disassembly with less loss of function than many alternatives.

Snap-on fasteners *can* support DfD, but not consistently—because some designs require special tools or can break during disassembly—so they must be evaluated case-by-case.

EU furniture procurement guidance reinforces this logic indirectly by noting that recycling and recovery are often complicated due to component separation difficulties, and therefore encourages furniture that is easy to disassemble and supports material separation.

4.4.5. Practical DfD guidelines for furniture design (what to do at the design stage)

A furniture DfD review proposes eight design guidelines to ensure the design supports disassembly: develop web-accessible disassembly instructions, prioritise access to fast-wearing components, prioritise modularity, standardise parts in modules, label components, enable independent component removal, use materials that withstand repeated disassembly, and employ fully disassemblable joints.

These guidelines align with procurement expectations that emphasise repairability, spare parts availability, disassembly, and durability as practical mechanisms to extend product life and reduce premature end-of-life waste.
Below is an SME-oriented version of DfD guidance (use it as a concept/prototype checklist):

A) Plan for disassembly early (not as an afterthought)

- Define an intended **disassembly sequence** (what comes off first, what tools are needed, what must stay intact).
- Ensure parts that need regular replacement (wear parts) are reachable early in the sequence.

B) Use reversible connections where it matters most

- Prefer fasteners that allow repeated disassembly (e.g., cam/bolt systems, other fully disassemblable solutions) over permanent bonding where repair and separation are required.

C) Reduce complexity and standardise interfaces

- Minimise the number of fastener types and tools required (lower repair time and errors).
- Standardise hole patterns and module interfaces so parts can be substituted or upgraded.

D) Enable clean material separation at end-of-life

- Avoid unnecessary multi-material bonding that prevents separation of wood/panels, metals, plastics, textiles/foam.
- Design “material islands” (e.g., upholstery module separable from frame) that can be routed to appropriate recovery.

E) Document for repairers and recyclers

- Provide clear disassembly instructions and component identification (materials and part codes), supporting repair and correct end-of-life routing.

Tip: During prototyping, time how long it takes to access and replace one high-wear component (e.g., hinge, glide, upholstery cover). If the time is not competitive with replacement purchasing, repair will not scale in SMEs.

4.4.6. End-of-life (EoL) planning: mapping components to realistic pathways

End-of-life planning is the process of deciding—already at the design stage—how each component should flow after use: **reuse, refurbishment, remanufacturing, repurposing, recycling**, or in the worst case disposal. Because furniture often contains multiple materials and complex joints, EoL planning must be grounded in what is technically separable and economically feasible, which is precisely what DfD addresses.
A practical furniture end-of-life plan typically includes:

Step-by-step EoL plan template

Step 1 — Break the product into components/modules List major modules: frame, surfaces, legs/base, hardware (hinges/bolts), upholstery (fabric, foam), glides/castors, packaging (if relevant).

Step 2 — Identify material types for each component Identify whether each component is wood/panel, metal, plastic, textile, foam, glass, etc., because material separation strongly affects recycling feasibility.

Step 3 — Assign a preferred recovery pathway for each component

- **Reuse**: intact modules that can be redeployed or resold.
- **Refurbishment**: modules that can be restored cosmetically or functionally (e.g., re-upholstery, refinishing).
- **Remanufacturing**: components that can be restored to "as new" performance and reintegrated (more common in contract/office furniture).
- **Recycling**: material streams that can be separated cleanly; avoid mixed or contaminated streams where possible.

Step 4 — Identify barriers and design fixes For each component pathway, record what prevents recovery (e.g., glued upholstery, mixed materials, inaccessible fasteners), and propose design changes (switch to reversible fasteners; separate materials; modularise upholstery).

Step 5 — Define "information to pass on" Specify what the product should communicate to repairers/recyclers (fastener types, disassembly steps, materials list), because lack of information is repeatedly identified as a barrier for effective repair and recycling.

4.4.7. Disassembly design and material recovery: how they are connected

EU furniture procurement evidence notes that end-of-life impacts and recycling outcomes vary substantially by materials used and that recovery is often complicated by **difficulty separating components**, making design choices a key determinant of recovery. In other words: even if a product uses "better" materials, poor disassembly design can prevent those materials from being recovered in clean streams, lowering recycling quality and increasing disposal.

The furniture joinery review reinforces this relationship by showing that joint choice determines whether disassembly is destructive (non-disassemblable), economically inefficient (conditionally disassemblable), or feasible and repeatable (fully disassemblable).

This directly influences material recovery because destructive or difficult disassembly increases contamination and reduces the likelihood that parts can be reused, refurbished, or recycled into high-quality applications.

A circular furniture design case study literature also frames DfD as a strategy that increases the possibility of repair, remanufacturing, and recycling, underscoring that disassembly is a prerequisite for multi-life cycles.

Key concept: Material recovery rates and the quality of recovered streams depend on how easily a product can be disassembled into clean, non-contaminated components and materials.

4.4.8. Example (workplace-relevant): end-of-life plan for a simple chair

This example illustrates how learners can apply DfD and EoL planning during WBL tasks using a common furniture item.

Chair modules: frame, seat, backrest, upholstery cover (optional), foam (optional), fasteners, glides.

Preferred pathways:

- Frame: reuse or refurbishment (refinish), or remanufacturing if designed for repeated cycles.
- Upholstery cover: refurbishment (replace), recycling only if separable and material-compatible.
- Foam: often challenging; improve by making it removable as a module and avoiding permanent bonding to other materials.

Design improvements: select fully disassemblable joints for major modules; standardise fasteners; ensure independent component removal; provide disassembly instructions and part identification.

4.4.9. Unit summary (takeaways)

- Furniture end-of-life recovery is often limited by **component separation difficulties**, so DfD is a primary lever for circularity.
- Only **fully disassemblable** joinery solutions consistently align with DfD; cam/bolt and expandable fasteners are highlighted as strong candidates, while snap-on solutions require careful evaluation.
- An end-of-life plan should map components to realistic pathways (reuse/refurbish/remanufacture/recycle) and identify design barriers and fixes.
- Better disassembly design increases the feasibility and quality of material recovery and supports higher-value loops like repair and refurbishment.

4.4.10. Quick knowledge check (5–10 minutes)

1. **Explain** why design for disassembly improves circularity in furniture and name two loops it enables.
2. **Identify** two joinery/fastening approaches that support fully disassemblable furniture and one that is typically non-disassemblable.
3. **Develop** a simple end-of-life plan for a furniture product by mapping at least five components to reuse/refurbish/remanufacture/recycle pathways.
4. **Analyse** how one design choice (e.g., adhesives, mixed materials, inaccessible fasteners) affects material recovery quality.

4.5. User-Centred Circular Design: Aesthetics, Function, and Sustainability

This subtopic explains how to balance **user expectations** (aesthetics, comfort, function, usability) with **circular design principles** (durability, repairability, disassembly, safe materials) to create furniture products that succeed in the market while enabling longer use and higher-value circular loops.
It shows why user-centred design is a practical enabler of circularity: products that people **want to keep**, can **use comfortably**, and can **maintain/repair easily** are less likely to be prematurely replaced and discarded.

4.5.1. What "user-centred circular design" means

User-centred design (UCD/HCD) is an approach in which design decisions are based on an explicit understanding of users, their tasks, and their context of use, and are refined through evaluation in an iterative process.
Although ISO 9241-210 is focused on interactive systems, its core principles—understanding users and contexts, involving users, iterative evaluation, addressing the whole experience—translate well to furniture because furniture is also a "human-system" product: people sit, move, touch surfaces, clean, carry, assemble, and live with it daily.
In circular furniture, user-centred design is not separate from sustainability—**it enables it**. If products are uncomfortable, hard to maintain, too heavy to move, or quickly look "worn out," users replace them sooner, reinforcing the linear pattern the circular economy tries to overcome.

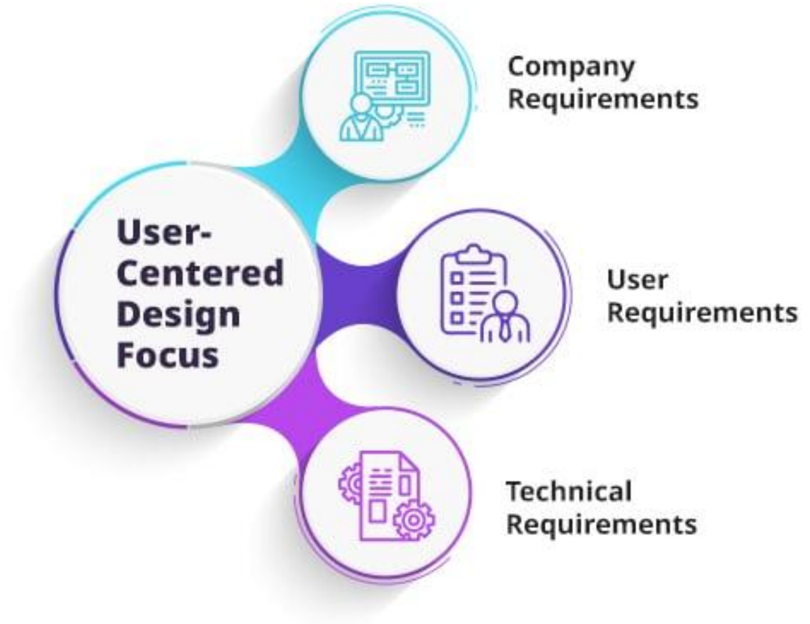

Figure 8. *User centered design focus* (Source: https://www.analytixit.com/)

Key concept: Circular design succeeds when users keep products longer, repair them, pass them on, or return them for refurbishment—so circular features must be aligned with user needs and perceived value.

4.5.2 Why aesthetics and function matter for circular outcomes

Furniture has both a **technical life** (it can still function) and a **aesthetic life** (style, comfort, status, fit in a space). Circular strategies often fail when perceived life is short—even if the product is structurally fine—because replacement becomes a "design choice" rather than a failure.

This is why many circular design frameworks put strong emphasis on **care, repair, adaptation, and refurbishment**, not only on recycling.

The IKEA Circular Product Design Guide explicitly frames circularity as keeping products and materials in circulation through **reuse/repair, refurbishment, remanufacturing, and recycling as a last resort**, and it also reflects customer expectations and behaviours as a key driver for circular design choices.

4.5.2. Practical strategies to balance user value with circularity

Below are practical strategies that preserve aesthetics and function **while increasing circular performance**.

A) Design for long-term satisfaction (comfort + "aesthetic durability")

- Use timeless proportions and finishes that age well, reducing premature replacement driven by style changes.
- Make high-wear, highly visible parts (e.g., covers, arm pads, table tops) **replaceable** so refurbishment restores "like-new" appearance without replacing the whole product.

B) Make circular actions easy for the user (care, repair, pass-on)

Many circular behaviours fail not because users disagree, but because effort is too high. IKEA notes that customers often struggle to pass on products they believe still have value, and the guide highlights designing products with circular capabilities to support reuse and repair in the customer's home. Practical design responses include:

- clear assembly/disassembly instructions and simple tool requirements,
- accessible fasteners for basic repairs,
- modular parts that can be replaced quickly,
- "care cues" (surface care guidance, cleaning compatibility) embedded in documentation.

C) Reduce trade-offs by using procurement-ready criteria as a "quality bar"

EU Green Public Procurement (GPP) criteria for furniture recommend requirements that directly support both user value and circularity, including durability, repairability, spare parts availability, ease of disassembly and material separation, and warranties/service agreements.

Design teams can use these as a practical checklist to avoid "green but unusable" solutions and to meet buyer expectations in B2B/public markets.

4.5.3. User-centred design methods that work well for furniture SMEs

Human-centred design standards emphasise understanding context of use, specifying requirements, producing solutions, and evaluating designs iteratively.

In furniture SMEs, these steps can be implemented with lightweight methods:

A) Context-of-use mapping (who, where, how)

Define: who uses the furniture (age, mobility, workplace/home), where it is used (office, school, hospitality), and how it is maintained (cleaning, moving, stacking, reconfiguration).

This prevents design decisions that look good on paper but fail in real use (e.g., surfaces that stain easily in hospitality, joints that loosen under frequent moving

B) Personas (simple, evidence-based)

A persona is a structured description of a user type's goals, behaviours, and pain points; it helps teams maintain empathy and align decisions around real needs rather than internal preferences. For circular furniture, include circular-relevant attributes in personas (e.g., willingness to repair, space constraints, need to relocate furniture, maintenance capacity

C) User journey mapping for "ownership over time"

Map the user journey beyond purchase: delivery, assembly, daily use, cleaning, minor repairs, relocation, passing on/selling, or returning for refurbishment.

This makes circular "touchpoints" visible—where design can enable reuse, repair, and refurbishment.

D) Rapid prototype evaluation (experience + circular tests)

Evaluation should happen early and iteratively, and should address the whole user experience. For furniture, combine experience tests (comfort, stability, usability) with circular tests (time-to-repair, disassembly sequence, replaceable modules).

4.5.4. Case examples: what "successful circular furniture" looks like (transferable lessons)

This section provides examples of circular furniture approaches that balance user needs with circular strategies. They are included as learning references—learners should extract *transferable* design lessons, not copy designs.

A) Case example 1 — IKEA circular loops + customer-centred circular capabilities

IKEA's guide defines circular products as having built-in capabilities for convenient **reuse/repair, refurbishment, remanufacturing, and recycling (last resort)** and explicitly discusses circularity through the eyes of customers and common behavioural barriers.

Transferable lessons for SMEs:

- design for disassembly and reassembly supports moving, repair, and secondhand markets,
- standardised parts support easy repair and replacement,
- user guidance and services are part of circular performance, not an "extra."
-

B) Case example 2 — Steelcase "Circular by Steelcase" (reuse/repair/remake/recycle service model)

Steelcase describes end-of-use services focused on **reuse, repair, remanufacturing ("remake"), and recycling**, including remade chairs with warranty and claims of lower emissions versus new production for remanufactured chairs.

Transferable lessons for SMEs: [steelcase.com]

- design for disassembly is supported by service infrastructure,
- warranties and repair services help extend user trust and product life,
- remanufacturing requires modular replaceable parts and consistent interfaces.

C) Case example 3 — Gispen circular design + refurbishment and circular hub services

Gispen describes circular furniture as high-quality, timeless, and easy to disassemble, enabling repair or replacement of damaged parts and supporting refurbishment services (e.g., reupholstery, replacing desktops).

Transferable lessons for SMEs: [gispen.com]

- timeless aesthetics reduce premature replacement,
- designing for separability supports quick repair and reuse,
- offering refurbishment increases value retention and customer loyalty.

4.5.5. A practical tool: the User–Circularity Balance Checklist (for concept review)

Use this checklist in concept selection and prototype review to keep aesthetics/function aligned with circular performance.

User value (must not degrade)

- Comfort and ergonomics fit the context of use.
- Usability: assembly and daily interaction are simple and tolerant of user error. [nist.gov], [iso.org]
- Aesthetics: appearance is acceptable and can age/refurbish well.

Circular value (must be enabled)

- Durability: structure and surfaces resist typical wear; warranty/service expectations can be met.
- Repairability: common failure parts are accessible; spare parts strategy exists.
- Disassembly: main modules can be separated with common tools; materials can be separated into clean streams.
- Information: clear care/repair/disassembly guidance exists for users and service partners.

Tip: If a circular feature adds user friction (harder assembly, less comfort, worse aesthetics), redesign the feature—because user rejection shortens product life and cancels circular benefits.

4.5.6. Developing a user-centred brief for a circular furniture product (template)

A strong user-centred brief makes circular goals measurable while protecting user value.
Brief elements (minimum):

1. **User group & context of use** (where, frequency, constraints).
2. **Primary functional requirements** (what the product must enable).
3. **Aesthetic requirements** (style constraints, “aging well,” refurbishability).
4. **Circular requirements** (durability target, repair access, disassembly, material separation).
5. **Service and information requirements** (spare parts period, repair instructions, care guidance).
6. **Evidence to collect** (prototype tests: comfort + time-to-repair + disassembly steps).

4.5.7. Unit summary (takeaways)

- User-centred design principles (context understanding, user involvement, iterative evaluation, whole experience) support circularity by extending product life through satisfaction and usability.
- Circular actions must be easy (repair, care, pass-on, refurbishment) to become real behaviour—design should reduce friction.
- EU procurement criteria and industry case approaches show that durability, repairability, spare parts, disassembly and warranties/services are practical market signals—and can be used as design checklists.
- Successful examples combine product design (modularity, disassembly) with services (repair/refurbish/remake) and user-facing information.

4.5.8. Quick knowledge check (5–10 minutes)

1. **Explain** two human-/user-centred design principles and how each supports circular outcomes in furniture.
2. **Identify** three design strategies that increase circularity without reducing user value (comfort/aesthetics/function).
3. **Analyse** one circular furniture case example and list two transferable lessons for SMEs.
4. **Draft** three bullet points for a user-centred circular brief (user context + one circular requirement + one evidence/test).

5. Activity and exercise template

5.1. Module I Activity 1 Circularity Audit and Redesign Proposal

Learners analyse an *existing* furniture product (or a real SME product) and produce a redesign proposal that improves circularity **without reducing user value**

Field	Instructions
Activity number	Module I Activity 1
Activity title	Circularity Audit and Redesign Proposal
Type	Small group

Duration	2–3 school hours in class + optional 1–2 hours in company/WBL context
Learning outcome(s) addressed	Reference the LO1, LO2, LO3
Materials needed	Product sample or photos + basic measurements; BOM if available; simple tools for inspection; template worksheet

5.1.1. Learner instructions (step-by-step)

1. **Select a product** (chair / small table / cabinet module / desk component) and describe its intended use and users (who, where, frequency).
2. **Map linear vs circular**: write 5–7 bullet points describing the current linear flow and where circular loops could occur (maintenance, repair, reuse, refurbishment, recycling).
3. **Identify hotspots**: based on furniture evidence that materials/components dominate impacts, list the top 3 impact drivers for this product (e.g., materials, coatings/chemicals, complex assemblies).
4. **Score the design** against circular design principles (durability, modularity, repairability, adaptability) and justify each score in 1–2 sentences.
5. **DfD check**: identify all joining/fastening types (glue, staples, screws, cam/bolt etc.) and classify them as non-/conditional-/fully disassemble where relevant.
6. **End-of-life plan**: create a simple component map (at least 8 components) and assign each one to a pathway: reuse / refurbish / remanufacture / recycle; explain two barriers and two design fixes.
7. **User-centred circular brief**: write a 6–10 bullet brief that includes: user needs, aesthetic expectations, functional requirements, and circular requirements (repair, disassembly, spare parts, care).
8. **Redesign proposal**: propose **at least 3 improvements** (minimum: one repairability/DfD improvement, one materials/eco-design improvement, one user-value improvement) and justify each by linking to circular loops and user acceptance.

5.1.2. Expected output / deliverable

A short portfolio (3–5 pages or slide deck) containing:

- linear vs circular map + value retention strategy,
- circular principle scores + evidence,
- disassembly assessment + end-of-life component pathway map,
- user-centred brief + redesign proposal (3+ changes).

5.1.3. Assessment evidence (what you can grade later)

- Correct use of circular concepts and loops
- Justified eco-design choices aligned with hotspot logic (materials/components)
- Practical DfD improvements using appropriate fastening logic
- Clear user-centred requirements that protect function/aesthetics

5.2. Module I Activity 2: Design & Build a Circular Mini-Prototype + Disassembly & Repair Test

Learners **design and make a small prototype** (mini furniture or object) following all module principles, and demonstrate circular performance via simple tests and documentation.

Field	Instructions
Activity number	Module I Activity 2
Activity title	Design & Build a Circular Mini-Prototype + Disassembly & Repair Test
Type	Small group (2-4)
Duration	6–10 school hours total (can run across several days or partly in-company), depending on workshop access and complexity
Learning outcome(s) addressed	Reference the LO4, LO5, LO6
Materials needed	wood/panels or reclaimed offcuts; standard fasteners (prefer a small set); basic tools; if possible CNC machine, optional finish; documentation template.

5.2.1. Learner instructions (step-by-step)

1. **Create a user-centred brief**: define a target user and context, functional requirements, aesthetic requirements, and circular requirements (repair, disassembly, modular parts, materials).
2. **Set circular loops**: define how the object will support reuse/repair and what refurbishment could look like; state recycling as last resort.
3. **Eco-design concept selection**: generate two concepts and choose one using a simple eco-design decision matrix focusing on materials, durability, repair/disassembly, and chemicals/finishes.
4. **Design for disassembly**: choose joinery/fasteners that are *fully disassemblable* where possible; reduce fastener types; ensure independent component removal.
5. **Build the prototype** and record a basic BOM (bill of materials) and assembly sequence.
6. **Run two simple tests**:
   - **Time-to-repair test:** simulate replacing one wear component (e.g., leg/glide, top surface panel, hook element) and measure minutes to complete. (Repairability is increasingly central in product policy and procurement criteria.)
   - **Disassembly test:** disassemble to main material streams and confirm no destructive steps are required.
7. **Prepare an end-of-life plan** mapping each part to reuse/refurbish/recycle streams and noting what information a repairer/recycler needs.
8. **User feedback**: ask at least two users (peers or workplace mentor) to test usability/fit/aesthetics and record 3 improvement notes. (Iterative evaluation is a core human-centred principle.)

6. Activity and exercise template

A prototype + a documentation pack (2–4 pages or slides):

- user-centred circular brief,
- concept selection rationale (eco-design matrix summary),
- BOM + assembly/disassembly steps (with fastener list),
- repair test time + disassembly test notes,
- end-of-life plan (part → pathway).

6.1.1. Assessment evidence (what you can grade later)

- Circular principles applied in physical design (durability/modularity/repairability)
- DfD quality (fasteners appropriate, low complexity, non-destructive separation)
- User-centred fit (function/aesthetics validated; improvements based on feedback)
- Documentation quality (clear instructions enable reuse/repair/refurbish pathways)

6.1.2. How these two exercises together cover all five units (quick mapping)

- **Exercise 1** builds analytical competence: CE foundations, circular design assessment, eco-design decisions, DfD/EoL mapping, and user-centred brief creation.
- **Exercise 2** proves capability through making: prototype built using circular principles + testing + documentation for repair/disassembly and user experience.

7. Assessment criteria

7.1. Competency descriptors linked to each learning outcome

Assessment in **Module I: Circular Design Thinking in Furniture Production** is based on the principle that learners should demonstrate not only conceptual understanding, but also the ability to apply circular economy thinking to realistic furniture design and SME workplace situations. In line with the Toolkit methodology, assessment should therefore combine **knowledge**, **analysis**, **practical decision-making**, and **work-based evidence**. Evidence may include short written responses, product analyses, redesign proposals, annotated sketches, component maps, end-of-life plans, and prototype documentation.
Three achievement levels are recommended for all learning outcomes:

- **Basic** – the learner demonstrates partial understanding and can identify relevant ideas, but with limited justification or incomplete application.
- **Proficient** – the learner demonstrates clear understanding, uses appropriate terminology, and applies circular design principles correctly in a furniture context.
- **Advanced** – the learner demonstrates confident and well-structured reasoning, makes justified design decisions, and connects circular principles to practical SME and work-based learning realities.

7.2. LO1 – Explain circular economy principles in furniture

The learner should be able to define the circular economy and explain its core principles in the context of furniture production.

- At **Basic** level, the learner can describe circular economy in general terms and mention some relevant strategies such as repair or reuse.
- At **Proficient** level, the learner clearly explains the difference between circular and linear thinking in furniture and identifies several relevant value-retention strategies.
- At **Advanced** level, the learner explains circular economy as a system-level design approach and links it convincingly to material use, product lifetime, and end-of-life planning in furniture SMEs.

7.3. LO2 – Compare linear and circular production models

The learner should be able to distinguish between linear and circular production models and identify differences in resource use, waste generation, and value retention.

- At **Basic** level, the learner identifies a few simple differences between the two models.
- At **Proficient** level, the learner compares both models across several dimensions, including materials,

waste, repair, and recovery.

- At **Advanced** level, the learner explains the implications of both models for SME practice, including competitiveness, service models, and sustainability expectations.

7.4. LO3 – Apply circular design principles to improve a furniture product

The learner should be able to apply the principles of durability, modularity, repairability, and adaptability to an existing furniture design.

- At **Basic** level, the learner proposes simple improvements, but the connection to circularity may remain weak.
- At **Proficient** level, the learner proposes at least three relevant and feasible design improvements and explains their benefits.
- At **Advanced** level, the learner presents an integrated redesign logic in which durability, modularity, repairability, and user value are balanced in a coherent solution.

7.5. LO4 – Use an eco-design decision framework from concept to prototype

The learner should be able to assess design/material options using sustainability criteria.

- At **Basic** level, the learner identifies some environmental aspects but applies them inconsistently.
- At **Proficient** level, the learner uses a simple decision framework and justifies choices using criteria such as materials, emissions, durability, and end-of-life options.
- At **Advanced** level, the learner applies life-cycle thinking systematically, identifies key hotspots, and demonstrates reasoned selection of the most sustainable concept.

7.6. LO5 – Design for disassembly and end-of-life planning

The learner should be able to develop a basic DfD and end-of-life plan for a furniture product.

- At **Basic** level, the learner identifies some components and possible recovery pathways, but the plan may remain incomplete.

- At **Proficient** level, the learner maps most components correctly and proposes realistic disassembly and recovery pathways.
- At **Advanced** level, the learner presents a clear and well-structured DfD strategy, identifies barriers such as mixed materials or inaccessible fasteners, and proposes improvements that increase recovery quality and disassembly efficiency.

7.7. LO6 – Evaluate circularity while balancing user needs

The learner should be able to evaluate circular performance while considering aesthetics, function, and user requirements.

- At **Basic** level, the learner recognises that usability and circularity must be considered together.
- At **Proficient** level, the learner develops a short user-centred improvement proposal that maintains both function and aesthetic quality while increasing circularity.
- At **Advanced** level, the learner demonstrates the ability to balance technical, environmental, and user-centred criteria and to justify design decisions in terms of long product life, user acceptance, and practical feasibility.

Overall, assessment in Module I should reward learners who can move beyond theory and demonstrate the ability to **translate circular economy concepts into design decisions, product improvements, and workplace-relevant outputs**. This supports the wider objective of the Toolkit: building circular design capacity in furniture VET and SME practice through applied, work-based learning.

8. Instructions for VET trainers and WBL coordinators

This module is designed to help learners understand how circular economy thinking can be translated into **practical design and production decisions** in the furniture sector. Trainers and WBL coordinators play a key role in ensuring that the module is not delivered as abstract sustainability theory, but as **applied, workplace-relevant learning** that reflects the realities of furniture SMEs, including constraints related to materials, costs, manufacturing methods, and customer expectations. The overall teaching approach should therefore combine **focused theory**, **guided analysis**, **real product examples**, and **practical outputs**.

8.1. General delivery approach

VET trainers should present the module as a progression from **core circular economy concepts** toward **practical design application**. Learners first need to understand the logic of circularity (closed loops, value retention, linear vs. circular models), and then progressively apply this logic to design principles, eco-design choices, disassembly strategies, end-of-life planning, and user-centred design decisions. For this reason, it is strongly recommended that trainers use one reference product throughout the module—for example, a chair, a small table, a cabinet module, or a real product provided by a partner SME. This helps learners connect all five content units to one coherent case rather than treating each topic separately.

Where possible, teaching should include real furniture products, prototypes, drawings, specification sheets, assembly instructions, or bills of materials, because the methodology of the Toolkit explicitly promotes work-based and workplace-oriented learning. Trainers should encourage learners to look at furniture not only as finished products, but also as systems of materials, components, fasteners, service needs, and end-of-life pathways.

8.2. Role of the VET trainer

The VET trainer is responsible for structuring the learning process, explaining concepts clearly, and helping learners translate sustainability language into practical design reasoning. A trainer should:

- introduce each unit using **short, focused input**, not long lectures;
- connect every concept to a **visible product feature** or **real SME practice**;
- encourage learners to justify their ideas using circular principles, not only intuition;
- support learners in identifying trade-offs between sustainability, manufacturability, cost, and user expectations;
- reinforce the use of correct professional vocabulary, such as **durability**, **repairability**, **modularity**, **design for disassembly**, **material separability**, and **value retention**.

The trainer should also ensure that learners document their thinking. Even simple outputs—such as annotated sketches, comparison tables, component maps, or short redesign proposals—are important because they provide evidence of competence and prepare learners for later assessment.

8.3. Role of the WBL coordinator and workplace mentor

The WBL coordinator and workplace mentor help bridge the gap between classroom learning and company reality. Their role is especially important when the module is delivered with or through SME partners. They should help provide:

- access to a **real product**, component, or sample assembly;
- simple workplace documentation such as a drawing, BOM, repair case, or packaging/assembly information;
- insight into common **failure points**, service requests, material choices, or joining methods used in the company;
- practical feedback on whether learner proposals are realistic in terms of production and service operations.

Mentors do not need to teach theory. Their value lies in helping learners understand what is **feasible, useful, and high-impact** in a real SME context. For example, they can explain why certain joints are currently used, what parts are hard to replace, or which customer complaints occur most often. This gives circular design thinking a workplace anchor.

8.4. Preparation before delivery

Before the module starts, trainers and WBL coordinators should agree on a common teaching setup. Ideally, they should prepare the following:

- one **reference furniture product** or a set of detailed product photographs;
- a basic **product information pack** (dimensions, materials, drawings, assembly information, or BOM if available);
- a short list of **workplace-relevant issues** to explore, such as damaged components, difficult repairs, mixed materials, or non-reversible fixings;
- activity worksheets or templates for learners to complete during the session.

If workshop-based demonstration is planned, trainers should also ensure that tools, health and safety requirements, and access conditions are clarified in advance. Learners should know whether they will only inspect products or also disassemble, compare, and test components.

8.5. Guidance by content unit

For **Foundations of Circular Economy in the Furniture Sector**, trainers should keep theory simple and practical. The most effective approach is to show one furniture product and ask learners: *What happens to this product in a linear model? What would change in a circular model?* Trainers should guide learners to identify the six loops (maintain, repair, reuse, refurbish, repurpose, recycle) and to understand why keeping a product in use retains more value than breaking it down into raw material.

For **Principles of Circular Design**, teaching should focus on physical product features. Trainers should ask learners to inspect the product and identify which parts affect durability, which parts could become modules, which failure points need repair access, and which material combinations could prevent future recovery or refurbishment. The emphasis should be on practical reasoning: *What would you change, and why?*

For **Eco-design Strategies**, trainers should introduce a simple decision framework rather than full life cycle assessment. It is sufficient to compare two material or design alternatives using criteria such as material impact, separability, hazardous substances, durability, repairability, and end-of-life options. Learners should understand that eco-design is a structured decision process and that early design choices determine later environmental performance.

For **Design for Disassembly and End-of-Life Planning**, the trainer should use product assembly as the main teaching object. Learners should analyse joinery and fastening methods, identify whether a product can be taken apart without damage, and map components to pathways such as reuse, refurbishment, remanufacturing, or recycling. If possible, this unit should include a visual or physical disassembly demonstration.

For **User-Centred Circular Design**, trainers should emphasise that circular products must still be desirable, functional, and easy to live with. Learners should be guided to consider the user journey: buying, using, cleaning, moving, repairing, and eventually passing on or returning the product. Exercises should help learners understand that poor comfort, weak aesthetics, or difficult maintenance can shorten product life even if the product is technically repairable.

8.6. Assessment and evidence collection

Trainers should assess both **understanding** and **application**. The most suitable evidence in this module includes:

- a short comparison of linear and circular thinking for one furniture product;
- a redesign proposal with two or three circular improvements;
- a basic design-for-disassembly and end-of-life plan;
- a short user-centred product brief or product evaluation.

WBL coordinators and mentors may contribute to assessment by confirming whether learner outputs are realistic and relevant to company practice. However, the main focus should remain on whether learners can **justify decisions using circular design logic**, rather than on whether they have arrived at one “perfect” technical solution.

Final recommendations

The module works best when trainers avoid overloading learners with terminology and instead consistently return to one key question:

How can this furniture product stay useful for longer, with less waste and more value retained?

If trainers and coordinators keep this question central throughout the module, learners are much more likely to understand circular economy not as an abstract policy idea, but as a practical design and production approach that is directly relevant to furniture SMEs.

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Figure references

Figure 1. Linear economy vs. circular economy. Adapted from Matheri, A. N., Sithole, Z. B., & Mohamed, B. (2024). Circular Economy and Sustainability, 4, 929–950. https://doi.org/10.1007/s43615-023-00329-3

Figure 2. Design for disassembly (AI generated)

Figure 3. Example decision matrix for chair. (AI Generated)

Figure 4. Example of eco-design (Ben Wilson – Chairfix – Eco-design). Adapted from AlterMaker. https://altermaker.com/eco-design-definition/

Figure 5. User-centered design focus. Adapted from AnalytixIT. https://www.analytixit.com/

Annex A: Learner worksheet

Module I – Circular Design Thinking in Furniture Production

Learner name: ______________________________________
Date: ____
Company / VET provider: ___________________________
Reference product: ________________________________

Part 1 – Product and user context

1.1 What product are you analysing or designing?
(Example: coffee table, chair, small shelf, cabinet module)
....
....

1.2 Who is the intended user?
(Who will use the product? In what type of environment?)
....
....

1.3 What is the main function of the product?
(What problem does it solve or what need does it meet?)
....
....

Part 2 – Circular economy foundations

2.1 Describe the product in a linear model
(How would the product typically be produced, used, and discarded in a "take–make–dispose" system?)
....
....

2.2 Describe the product in a circular model
(How could the product remain in use longer through maintenance, repair, reuse, refurbishment, or recycling?)
....
....
....
....

2.3 Which circular loops could apply to this product?

☐ Maintain
☐ Repair
☐ Reuse
☐ Refurbish
☐ Repurpose
☐ Recycle

Which is the highest-value loop for this product and why?

....
....

Part 3 – Circular design principles

Evaluate the product using the key circular design principles.

3.1 Durability

- What parts are most likely to wear out or fail first?
  ....
- How could durability be improved?
  ....

3.2 2 Modularity

- Which parts could be made replaceable or upgradeable?
  ....
- What would be the benefit of making them modular?
  ....

3.3 3 Repairability

- Can the product be opened and repaired easily?
  ☐ Yes ☐ Partly ☐ No
- What makes repair easy or difficult?
  ....

3.4 4 Adaptability

- Can the product be adjusted, reconfigured, or used in a different way?
  ☐ Yes ☐ Partly ☐ No
- Explain briefly:
  ....

Part 4 – Materials and eco-design decisions

4.1 Main materials used in the product

Component	Material	Easy to separate (Yes/No)	Notes

4.2 What is the main material or design "hotspot" in this product?

(Which material, component, or process is likely to have the largest impact?)

………

4.3 Compare two possible design or material options

Criteria	Option A	Option B)	Better option
Material impact			
Material impact			
Durability			
Repairability			
End-of-life options			

Chosen option and reason:

………

………

Part 5 – Design for disassembly (DfD) and end-of-life planning

5.1 What joining or fastening methods are used?

☐ Screws

☐ Bolts / cam fittings

☐ Glue

☐ Staples / nails

☐ Other: ______________________________

5.2 Can the product be disassembled without damage?

☐ Yes ☐ Partly ☐ No

5.3 Describe the disassembly process in 3–5 steps

1. ………
2. ………
3. ………
4. ………

5.4 4 End-of-life plan

Component	Pathway (reuse / refurbish / remanufacture / recycle)	Barrier	Proposed improvement

Part 6 – User-centred circular design

6.1 What makes this product attractive or valuable to the user?
(Consider aesthetics, function, comfort, convenience)
....
....
6.2 What could make users discard or replace it too early?
....
....
6.3 3 How could the design be improved so that users keep it longer?
....
....

Part 7 – Final improvement proposal

Write three circular improvements for this product
(At least one should address design, one materials or disassembly, and one user value)
Improvement 1
....
Why it helps: ....
Improvement 2
....
Why it helps: ....
Improvement 3
....
Why it helps: ....

Part 8 – Reflection
What did you learn from this task about circular furniture design?
....
....
....

Annex B: Assessment rubric

Scoring rubric for Module I – Circular Design Thinking in Furniture Production

Learner name: ____
Date: ____
Company / VET provider: ___________________________________
Reference product: ____

This rubric is intended for use by **VET trainers, WBL coordinators, and workplace mentors** to assess learner performance in Module I. It links directly to the six learning outcomes and may be applied to worksheets, redesign tasks, product analyses, prototype presentations, and WBL-based outputs.

Performance levels

- **1 = Basic** – limited understanding; partial or weak application
- **2 = Proficient** – clear understanding and correct application
- **3 = Advanced** – strong, well-justified, and workplace-relevant application

Assessment rubric table

Learning outcome	Assessment criteria	1 – Basic	2 – Proficient	3 – Advanced	Score
LO1 Explain circular economy principles in furniture	Understanding of circular economy concepts and value-retention logic	Gives a partial definition; identifies only a few circular ideas	Clearly defines circular economy and identifies relevant circular loops for furniture	Explains CE convincingly as a system-level design approach and links it to SME practice	
LO2 Compare linear and circular production models	Ability to distinguish linear and circular production models	Identifies only basic differences	Compares both models across resources, waste, and product life	Explains implications for production, service, and competitiveness in SMEs	
LO3 Apply circular design principles to improve a furniture product	Use of durability, modularity, repairability, and adaptability in product improvement	Suggests improvements with limited explanation	Proposes relevant design improvements and explains benefits	Presents a coherent and feasible redesign strategy balancing several circular principles	
LO4 Use an eco-design decision framework from concept to prototype	Selection and justification of design/material options using sustainability criteria	Uses only limited or unclear criteria	Applies a simple framework and justifies design choices with relevant criteria	Demonstrates structured life-cycle thinking and strong rationale for selecting the preferred option	
LO5 Design for disassembly and end-of-life planning	Identification of joining methods, disassembly logic, and realistic EoL	Identifies some parts and pathways, but	Produces a realistic disassembly and EoL plan for most components	Demonstrates clear DfD reasoning, identifies barriers, and proposes strong improvements	

Total score________________________________

Maximum score: 18 points

Suggested interpretation

- **15–18 points** = Excellent achievement
- **11–14 points** = Good achievement
- **7–10 points** = Satisfactory achievement
- **6 points or below** = Further development needed

Additional comments (for trainer / mentor)

Strengths:

....

....

Areas for improvement:

....

....

Recommended next step:

....

....

Funded by
the European Union

Module II

Sustainable Furniture Production & Product LCA

Document information

Item	Description
Document type	CBF Toolkit — Work-Based Learning Module
Module	Module II
Title	Sustainable Furniture Production & Product LCA
Programme	Erasmus+ CB-VET
Project	SUSFUR — Promoting Sustainable Furniture Production in the Western Balkan Through Strengthening the Linkages between Business Sector and VET Provider
Project number	101183370
Sector	Furniture manufacturing — circular economy
Main contributors	ESI & NH, with inputs from project partners
Status	Final approved version — cleared for publication

Table of contents

1. Module Overview

1.1 Learning context and purpose

This module introduces sustainable furniture production through a practical life-cycle perspective, helping learners understand how material choices, production processes, transport, product use, and end-of-life options influence the overall environmental performance of furniture products. The learning rationale reflects the growing need for furniture SMEs to move beyond general sustainability claims and towards evidence-based decision-making supported by material assessment, certification checks, Life Cycle Assessment (LCA), carbon footprinting, and waste minimisation practices.

The module is especially relevant for the furniture sector because furniture production relies on resource-intensive materials such as timber, engineered boards, metals, textiles, foams, adhesives, and surface finishes. These materials can generate significant environmental impacts through forestry, extraction, chemical use, energy consumption, emissions, and waste. At the same time, the sector has strong potential to improve sustainability through responsible sourcing, certified materials, recycled-content inputs, low-emission adhesives and finishes, efficient production planning, reuse of offcuts, and cleaner manufacturing practices.

The module supports practical, workplace-oriented learning aligned with current European sustainability expectations, where companies are increasingly required to measure, document, and reduce environmental impacts across the value chain. Learners are introduced to accessible tools and methods that can support SMEs in evaluating materials, identifying environmental hotspots, preparing simplified environmental fact sheets, calculating basic carbon footprints, and proposing realistic improvement measures on the shop floor.

1.2 Target audience

This module is designed for VET learners and early-career professionals preparing for roles in furniture manufacturing, product development, production planning, purchasing, quality control, sustainability coordination, and workshop supervision within furniture SMEs. It also supports VET trainers, WBL coordinators, and workplace mentors who need a structured framework to connect classroom learning with company practice. The module is suitable for learners who may not yet be specialists in sustainability or LCA but who need to understand how environmental performance can be assessed and improved through practical decisions in sourcing, design, production, and waste management.

1.3 Delivery format: Work-Based Learning orientation

The module is intended for Work-Based Learning (WBL) delivery, combining focused theory inputs with practical tasks that can be completed using real or simulated furniture products, bills of materials, supplier documentation, workshop observations, and basic production data from host SMEs.

Activities guide learners to translate sustainability concepts into concrete workplace actions, including checking FSC/PEFC or equivalent material certifications, comparing materials from an environmental perspective, identifying LCA system boundaries, collecting basic inventory data, calculating simplified carbon indicators, mapping material waste, and proposing clean production improvements.

Where possible, delivery should include observation-based learning in company settings, such as visits to the materials store, cutting area, assembly area, finishing area, packaging zone, and waste collection points. This allows learners to connect theoretical concepts such as life-cycle thinking, environmental hotspots, and material efficiency with real production decisions.

1.4 Scope, content focus and duration

The module focuses on the core essentials of sustainable furniture production and product LCA. It is structured around five main content areas:

1. **Sustainable and responsible material sourcing** Learners explore the main material categories used in furniture production, including timber, engineered boards, metals, textiles, foams, finishes, adhesives, and hardware. The focus is on environmental impacts, certification schemes, traceability, supplier documentation, and sustainable material selection.

2. **Introduction to Life Cycle Assessment for furniture products** Learners are introduced to LCA as a structured method for assessing environmental impacts across the full life cycle of a furniture product. Key concepts include functional unit, system boundaries, life-cycle stages, inventory data, environmental hotspots, and interpretation of results.

3. **Conducting a simplified LCA** Learners apply a step-by-step simplified LCA process suitable for VET and SME contexts. They collect basic data on materials, energy, transport, packaging, waste, and end-of-life treatment, then organise this information into a simple inventory table.

4. **Furniture carbon footprint and emission hotspots** Learners examine the main sources of greenhouse gas emissions in furniture value chains and practise calculating a basic product or process carbon footprint using simplified emission factors. The focus is on identifying where reduction measures will have the highest impact.

5. **Waste minimisation, energy efficiency and clean production practices** Learners analyse material waste and energy loss in furniture manufacturing and propose improvement measures using practical tools such as waste walks, material flow mapping, lean production principles, offcut reuse, improved process control, and closed-loop approaches.

1.5 Duration and two-day timetable

Total duration: 2 training days, 3–4 school hoursper day
Total guided learning time: approximately 6–8 school hours
The module can also be expanded with additional self-directed study, workplace data collection, or company-based assignments where more time is available.

Recommended sequencing for compact WBL delivery

Day 1: Sustainable material sourcing and life-cycle thinking

- **Short input:** Introduction to sustainable furniture production, key material categories, and the environmental relevance of timber, engineered boards, metals, textiles, foams, finishes, and adhesives.
- **Short input:** Certification and traceability, including FSC, PEFC, recycled-content claims, low-VOC materials, and supplier documentation.
- **Guided discussion:** Why material selection is often a major environmental hotspot in furniture production.
- **Practical task:** Conduct a rapid material sustainability audit for one furniture product using a bill of materials, supplier data sheet, label, or product specification.
- **Short input:** Introduction to Life Cycle Assessment, life-cycle stages, functional unit, and system boundaries.
- **Mini-exercise:** Define the functional unit and system boundaries for a selected product such as a chair, table, cabinet, or upholstered item.

Day 2: Simplified LCA, carbon footprint and production improvement

- **Short input:** Simplified LCA methodology and the role of inventory data, including materials, electricity, transport, packaging, waste, and end-of-life treatment.
- **Practical task:** Complete a simplified LCA inventory table for a representative furniture product or product component.
- **Short input:** Carbon footprinting and environmental hotspots in the furniture value chain.
- **Calculation exercise:** Use simplified emission factors to calculate a basic carbon footprint and identify the highest-impact life-cycle stage.
- **Short input:** Waste minimisation, energy efficiency, and clean production practices in furniture manufacturing.
- **Company-based or simulated WBL task:** Conduct a waste walk or production-process review and identify three sources of material waste or energy loss.
- **Wrap-up:** Prepare a short improvement proposal linking material choices, LCA findings, carbon footprint results, and waste-reduction opportunities.

This two-day structure keeps the module feasible for short-format VET delivery while still preserving the practical sequence of the topic: materials → life-cycle thinking → simplified assessment → carbon footprint → shop-floor improvement.

1.6 Prerequisites

VET Learners should have:

- Basic familiarity with common furniture materials, including wood, wood-based panels, metals, textiles, foams, finishes, adhesives, and hardware.

- Basic understanding of furniture production processes such as cutting, machining, assembly, finishing, packaging, and waste handling.
- Ability to read simple product information, such as sketches, basic drawings, bills of materials, supplier labels, or specification sheets.
- Basic numeracy skills for simple calculations involving quantities, percentages, distances, energy use, and emissions factors.

No prior specialist knowledge of Life Cycle Assessment, carbon accounting, or environmental certification is required. Foundational concepts are introduced progressively and applied through practical examples.

1.7 Expected learning outputs: evidence of competence

By the end of the module, learners should produce compact, workplace-relevant outputs such as:

- A short material sustainability audit for a furniture product, identifying key materials, certification status, environmental concerns, and possible alternative materials.
- A defined functional unit and system boundary for a furniture LCA case.
- A simplified life-cycle inventory table covering materials, energy, transport, packaging, waste, and end-of-life assumptions.
- A basic environmental fact sheet presenting simplified LCA findings and identifying the main environmental hotspots.
- A basic carbon footprint calculation for a furniture product, component, or production process.
- A short improvement proposal recommending practical measures to reduce emissions, material waste, energy use, or environmental risk.
- A workplace-based waste walk summary identifying major sources of waste and proposing realistic clean production measures.

2. Learning outcomes

The learning outcomes align with the progression of Module II topics — from sustainable and responsible material sourcing, through Life Cycle Assessment principles, simplified LCA practice, furniture carbon footprinting, and waste minimisation in production. They are designed to support practical Work-Based Learning tasks and to provide clear evidence of learner competence in furniture-sector sustainability.

LO1 — Identify and assess sustainability impacts of furniture materials

By the end of this module, learners will be able to IDENTIFY the main material categories used in furniture production, given a furniture product, bill of materials, or specification sheet, by correctly classifying at least five relevant material groups — such as timber, engineered boards, metals, textiles, foams, finishes, adhesives, or hardware — and explaining their main environmental impacts in relation to sourcing, processing, emissions, durability, and end-of-life options.

LO2 — Evaluate responsible material sourcing and certification evidence

By the end of this module, learners will be able to EVALUATE the sustainability credentials of furniture materials, given supplier information, product labels, certification documents, or procurement data, by identifying relevant evidence such as FSC, PEFC, recycled-content claims, low-VOC specifications, or formaldehyde-emission compliance, and by highlighting at least three potential red flags linked to unsustainable or poorly documented sourcing.

LO3 — Explain Life Cycle Assessment principles for furniture products

By the end of this module, learners will be able to EXPLAIN the purpose and structure of Life Cycle Assessment in the furniture sector, given a short product or company scenario, by accurately describing the four main LCA phases — goal and scope definition, life-cycle inventory, life-cycle impact assessment, and interpretation — and by defining the functional unit and system boundaries for a selected furniture product.

LO4 — Conduct a simplified LCA for a furniture product

By the end of this module, learners will be able to CONDUCT a simplified Life Cycle Assessment, given a representative furniture product and basic production data, by preparing a life-cycle inventory table that includes materials, energy use, transport, packaging, waste, and end-of-life assumptions, and by identifying the main environmental hotspots that should be prioritised for improvement.

LO5 — Calculate and interpret a basic furniture carbon footprint

By the end of this module, learners will be able to CALCULATE a basic carbon footprint for a furniture product, component, or production process, given simplified activity data and emission factors, by estimating greenhouse gas emissions across selected life-cycle stages and interpreting the results to identify at least three targeted emission-reduction measures.

LO6 — Propose waste minimisation and clean production improvements

By the end of this module, learners will be able to PROPOSE practical waste minimisation and clean production measures, given a workshop observation, waste walk, or production-process description, by identifying at least three sources of material waste or resource inefficiency and recommending realistic improvements such as better material nesting, offcut reuse, process control, preventive maintenance, closed-loop practices, or lean production actions.

3. WBL Context and Sector Relevance

3.1 Why this module is workplace-relevant for furniture SMEs

Furniture SMEs operate in a sector where material selection, production efficiency, energy use, finishing processes, transport, and end-of-life treatment directly influence both environmental performance and business competitiveness. Many sustainability impacts are created before the product reaches the customer, especially through the choice of timber, engineered boards, metals, textiles, foams, adhesives, coatings, and packaging. For this reason, sustainable furniture production cannot be treated as a separate environmental topic; it is closely connected to everyday decisions in purchasing, design, production planning, quality control, and waste management.

Module II is workplace-relevant because it gives learners practical methods for understanding and reducing these impacts. Instead of relying on general claims such as “eco-friendly” or “green”, learners are trained to look for evidence: certified timber, recycled-content materials, low-emission adhesives and finishes, supplier documentation, production data, energy use, waste quantities, and end-of-life options. This evidence-based approach is increasingly important for SMEs that need to respond to customer expectations, procurement requirements, sustainability reporting pressures, and emerging EU policy frameworks linked to circular economy, product transparency, and environmental performance.

The module also supports SMEs in identifying practical improvement opportunities that do not necessarily require large investments. Examples include selecting better-documented materials, reducing avoidable offcuts, improving nesting and cutting plans, separating waste streams, switching to lower-emission finishes, using recycled-content metals, improving packaging choices, and monitoring energy-intensive production steps. These actions can reduce environmental impacts while also improving material efficiency, cost control, quality consistency, and readiness for sustainability-oriented markets.

3.2 How sustainable production and LCA connect to everyday SME workflows

Module II links directly to common furniture SME workflows, especially where environmental decisions are already embedded in routine operations. The module helps learners recognise that Life Cycle Assessment, carbon footprinting, and sustainable sourcing are not only technical reporting tools; they are practical decision-support methods that can improve day-to-day production choices.

Key workplace touchpoints include:

Material and supplier selection

Furniture SMEs regularly choose between solid wood, wood-based panels, metals, textiles, foams, plastics, adhesives, surface finishes, and hardware. These choices are often influenced by cost, availability, performance, customer specifications, and delivery time. Module II adds sustainability criteria to this process by helping learners check material origin, certification status, recycled content, formaldehyde and VOC information, durability, repair potential, and recyclability. This supports better purchasing decisions and reduces the risk of using materials with unclear sourcing, high emissions, or limited end-of-life value.

Bills of materials and product documentation

A bill of materials is a central workplace document for production planning, costing, purchasing, and quality control. In this module, learners use the bill of materials as the starting point for material sustainability audits, simplified LCA exercises, and carbon footprint calculations. By linking each component to its material type, quantity, supplier data, environmental concern, and possible end-of-life pathway, learners develop a more systematic understanding of where environmental impacts are created and where improvements are most feasible.

Production planning and workshop efficiency

In furniture SMEs, workshop decisions such as cutting layouts, machining sequences, assembly methods, finishing schedules, and batch sizes affect material yield, energy use, rework, and waste generation. Module II connects these operational decisions to clean production principles. Learners examine how better planning, preventive maintenance, process stability, lean production methods, and improved material flow can reduce waste and improve environmental performance without disrupting normal production.

Finishing, adhesives, and indoor air quality

Furniture production often involves coatings, varnishes, adhesives, stains, solvents, laminates, and upholstery chemicals. These materials are important for durability and appearance, but they can also create environmental, occupational health, and indoor air quality concerns. Module II helps learners evaluate finishes and adhesives through a sustainability lens, including low-VOC options, restricted substances, formaldehyde emissions, durability, and compatibility with repair or refurbishment. This supports both compliance-oriented thinking and higher-quality product specification.

Energy use and carbon footprinting

Many SMEs do not have advanced environmental management systems, but they often have access to basic data such as electricity bills, machine use, transport distances, material quantities, and waste records. Module II shows learners how to use this information to calculate simplified environmental indicators and basic carbon footprints. This allows SMEs to identify emission hotspots and prioritise realistic actions such as improving machine efficiency, reducing rework, consolidating transport, improving packaging, or selecting lower-impact materials.

Waste management and material recovery

Furniture production generates offcuts, sawdust, packaging waste, rejected components, damaged panels, textile scraps, foam residues, and finishing-related waste. Module II introduces learners to workplace tools such as waste walks, material flow mapping, waste sorting, offcut reuse, and closed-loop thinking. These activities help learners identify where waste is generated, why it occurs, and how it can be prevented, reused, separated, or valorised before disposal.

3.3 Sector relevance: market access, procurement readiness and environmental transparency

For furniture SMEs, sustainability performance is increasingly connected to market access. Buyers in offices, hospitality, education, public buildings, retail, and international supply chains are asking for clearer evidence of responsible sourcing, reduced emissions, safer materials, durability, and end-of-life planning. SMEs that can provide reliable documentation are better positioned to respond to tenders, customer questionnaires, supplier audits, and sustainability-oriented procurement requirements.

Module II supports this readiness by helping learners understand the types of evidence that companies may need to collect and communicate. This includes timber certification, chain-of-custody information, recycled-content declarations, low-emission material specifications, LCA summaries, carbon footprint estimates, waste-reduction records, and environmental fact sheets. While the module does not require learners to carry out a full ISO-compliant LCA, it builds the foundational competence needed to understand LCA logic, collect basic inventory data, interpret hotspots, and communicate findings in a structured way.

This is especially important because environmental transparency is becoming a practical business requirement rather than a voluntary marketing choice. SMEs that understand their material flows, energy use, emissions, and waste streams are better able to improve products, respond to buyer demands, reduce costs, and prepare for future sustainability documentation requirements.

3.4 What Work-Based Learning looks like in this module: SME-integrated practice

The module is designed for practical WBL delivery and can be implemented using actual SME products, workshop observations, supplier documents, bills of materials, and simple production records. The learning tasks are intentionally compact so that they can be completed within a short training format while still producing workplace-relevant evidence.

Typical WBL learning evidence includes:

Material sustainability audit

Learners select one furniture product or component and identify the main materials used. They check available supplier information, certification evidence, recycled content, emission-related data, and potential sustainability risks. The output is a short material audit highlighting strengths, gaps, and improvement options.

Certification and supplier documentation review

Learners examine labels, certificates, technical data sheets, or supplier declarations and assess whether the information is sufficient to support responsible sourcing claims. They identify missing or unclear evidence and propose questions that an SME could ask suppliers before procurement.

Simplified LCA inventory table

Learners prepare a basic life-cycle inventory for a selected product, covering material quantities, production inputs, energy use, transport assumptions, packaging, waste, and end-of-life options. This task helps learners understand how product-level environmental assessment begins with structured data collection.

Functional unit and system boundary definition

Learners define the functional unit and system boundaries for a furniture product, such as one office chair used for a defined period, one table produced and delivered to a customer, or one cabinet manufactured for indoor use. This develops the discipline needed to make environmental comparisons fair and transparent.

Basic carbon footprint calculation

Using simplified activity data and emission factors, learners estimate greenhouse gas emissions for selected life-cycle stages. They then identify the largest emission sources and propose practical reduction measures.

Waste walk and clean production review

Learners observe or simulate a walk-through of the production area and identify sources of material waste, energy loss, rework, or inefficient handling. The output is a short improvement plan with practical measures such as better cutting optimisation, offcut storage, waste separation, preventive maintenance, or reduced packaging waste.

These outputs support the project methodology by ensuring that learners produce clear evidence of competence and that sustainability learning remains closely connected to workplace decision-making.

3.5 Role of workplace mentors and VET trainers: bridging learning and production reality

Because furniture SMEs differ in product type, machinery, supplier networks, production volume, and available data, trainers and workplace mentors play an important role in adapting the module to local realities. Their role is to help learners apply sustainability tools in a practical and realistic way, without creating unnecessary administrative burden for the company.

Workplace mentors can support learning by providing access to a product sample, bill of materials, supplier label, technical data sheet, production area, waste collection point, or typical repair/rework example. They can also explain why certain materials or processes are used, what constraints the company faces, and which improvements would be feasible in the short term.

Figure 1 *Local training in Albania;* Note. Photograph by ESI (2026).

VET trainers can support learners by simplifying technical concepts such as LCA, carbon footprinting, system boundaries, and emission factors, while maintaining enough accuracy for meaningful workplace application. Trainers should encourage learners to focus on “high-impact and feasible” improvements: actions that reduce environmental impacts, support compliance or customer expectations, and can realistically be implemented by SMEs.

3.6 Relevance for SMEs in the Western Balkans: practical transition needs

The module is designed with SME realities in mind, including limited time, limited access to advanced sustainability software, variable supplier documentation, and restricted investment capacity. For many furniture SMEs in the Western Balkans, the transition toward sustainable production will need to be gradual, practical, and closely linked to competitiveness.

Module II therefore emphasises accessible methods that can be implemented step by step. These include improving material documentation, prioritising certified or better-traceable materials, reducing waste through better planning, reusing offcuts, separating recyclable materials, selecting lower-emission finishes and adhesives, calculating simplified carbon indicators, and preparing basic environmental fact sheets for customers or procurement processes.

By focusing on practical workplace tools rather than complex reporting systems, the module helps SMEs begin the transition toward more sustainable production using the information and resources they already have. This makes the module relevant not only for environmental improvement, but also for quality management, cost reduction, customer trust, and long-term market readiness.

4. Content Units

4.1.1 The Three Main Types of Wood

Understanding the different types of wood and their applications is essential for evaluating the sustainability credentials of any furniture product. All wood used in furniture falls into one of three broad categories: softwoods, hardwoods, and engineered wood.

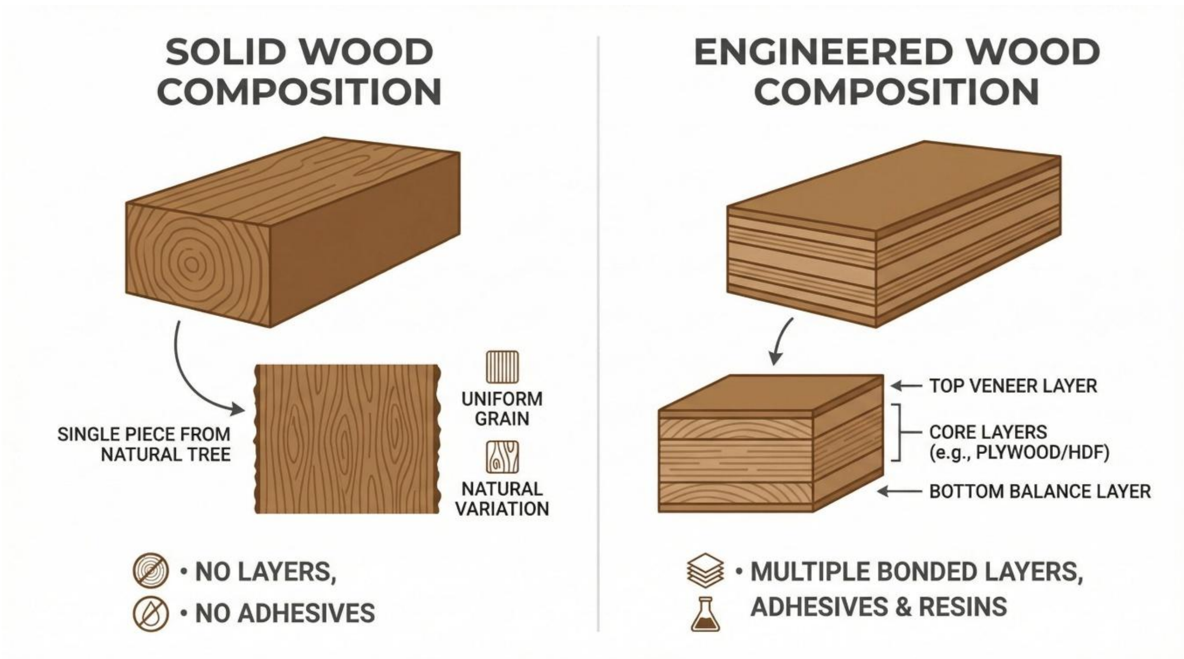


Figure 2 *Anatomy of Composite Wood Products* (Source: https://www.everwoody.com/solid-wood-or-engineered-wood/)

Softwoods

Softwoods are milled from conifer trees (Gymnosperms) — species that produce needles and cones, such as Pine, Cedar, Fir, Spruce, and Redwood. Despite the name, softwoods are not necessarily softer than hardwoods; the classification relates to the biology of the tree, not the density of the timber. Softwoods are widely used in construction framing and utility structures. Species from the cypress family, such as Cedar and Redwood, are prized for their natural resistance to rot and insects, making them suitable for exterior and outdoor furniture applications.

Hardwoods

Hardwoods come from deciduous trees (angiosperms) — trees that produce leaves and seeds, such as oak, maple, cherry, mahogany, and walnut. Many hardwood species are valued for their distinctive grain patterns and durability. Bamboo and Palm, though technically monocotyledons, are often grouped with hardwoods due to similar characteristics. Hardwoods are the primary category for premium and mid-range furniture production.

Engineered Wood

Engineered wood products are manufactured rather than naturally occurring. The main categories used in furniture production are:

Particle Board / Chipboard: Made from rough wood particles pressed between surface layers, typically finished with PVC or melamine edging. Cost-effective and versatile in colour and pattern, but the edged zones are vulnerable to moisture infiltration and ungluing over time.

MDF (Medium Density Fiberboard): Made from softwood fibres dry-pressed at high temperature and pressure. MDF has a fine, homogenous structure, smooth surface, and high strength. It can be processed with ornamental details and coatings, making it highly versatile in modern furniture design.

HDF (High Density Fiberboard): Similar to MDF but pressed at higher temperature and pressure, resulting in greater strength. Available in thinner sheets (3–4 mm), commonly used for furniture backs and drawer bottoms.

4.1.2 Key Wood Species in Furniture Production

Figure 3: *Different types of woods for furniture* (Source: https://www.cabinfield.com/blog/different-types-of-wood-for-furniture-picture-guide/?srsltid=AfmBOooqdlfCdORw97EDL3ToWuYbKMU_GAoEjnvfQGMdktdlwG0xyLyM)

The following table summarises key wood species commonly used in furniture production, noting their principal characteristics and sustainability considerations.

Species	Type	Key Characteristics & Applications
Oak (Red & White)	Hardwood	Beautiful grain, rot-resistant, excellent for staining. Prone to swelling; must be acclimatised. Ideal for premium furniture and flooring.
Pine	Softwood	Common, sustainable (fast-growing), economical. Good for staining and painting. Best for indoor use unless pressure-treated.
Maple (Hard & Soft)	Hardwood	Dense, fine grain. Hard maple used for flooring; soft (red) maple more workable for furniture. Grown in sustainable North American forests.
Walnut	Hardwood	Rich dark brown, fine grain, polishes well. Strong and easy to work. Premium pricing; used in cabinetry, decorative accents, and specialist items.
Cherry	Hardwood	Light pink that deepens to red over time. Takes clear finish well; most valued in natural state. Sustainable alternative to exotic hardwoods.
Beech	Hardwood	Uniform grain, excellent steam-bending properties. Affordable hardwood for chairs and curved furniture. Susceptible to humidity changes.
Bamboo	Grass (hardwood-equivalent)	Rapid-growing, strong, and durable. Natural wax coat requires sanding before adhesive or stain. Environmentally favourable sourcing profile.
Teak	Exotic hardwood	Naturally oily, highly rot-resistant. Premium outdoor furniture. Very long growing cycle (60 years); high price and sourcing risk. Look for certified sustainable sources.
MDF / Particle Board	Engineered	Cost-effective, uniform. Check for low-formaldehyde and CARB2-compliant products. Formaldehyde emissions are a key sustainability concern.

Table 2 — Key wood species and engineered boards in furniture production

4.1.1 Metals in Furniture Production

Steel and aluminium are extensively used in seating frames, table bases, and storage hardware. Both have high environmental impacts at the extraction and primary production stage, but also have excellent recycling economics.

- Steel contains an average of 30–35% recycled content globally. Electric arc furnace (EAF) steel produced from scrap has approximately 75% lower CO_2 emissions than virgin blast-furnace steel.
- Aluminium is energy-intensive to produce from bauxite, but infinitely recyclable. Secondary (recycled) aluminium requires only 5% of the energy of primary production. Specifying high-recycled-content aluminium alloys is a high-impact procurement decision.

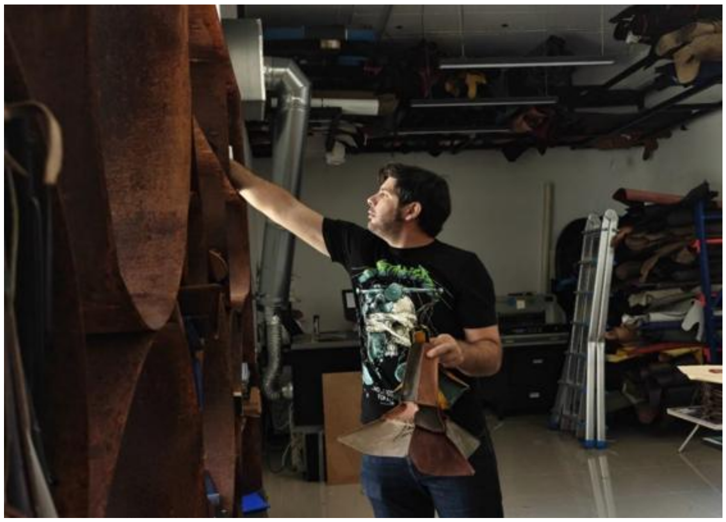


Figure 4 *Metal shelve unit produced at Opinga Craft workshop*; Note. Photograph by ESI (2026)

The table below summarises the principal metal alloys used in furniture frames and hardware:

Metal / Alloy	Key Properties	Sustainability & Applications
Cold-Rolled Steel (CRS)	High strength, precision tolerances, smooth finish. Corrodes without protective finish.	Best value structural frame material. Powder coat or galvanise to prevent corrosion. Recyclable at end of life.
Stainless Steel 304	Austenitic; strong, ductile, corrosion-resistant. Susceptible to chloride pitting.	Long service life with minimal upkeep. Use where appearance and durability are priorities.
Stainless Steel 316	Molybdenum-enhanced; superior chloride and chemical resistance.	Premium outdoor and coastal environments. Use 316L variant for welded sections. Higher cost.
Extruded Aluminium 6063	Lightweight, corrosion-resistant, complex hollow profiles. Powder coat or anodise.	Excellent recycled content available. Specify secondary aluminium. High design flexibility.

Cast Aluminium	Complex shapes, moderate strength. Quality depends on casting; T6 heat treatment improves consistency.	Lower strength than extruded; use for decorative and moderate-load components.
Brass C26000	Formable, decorative. Risk of tarnish; not for high structural loads.	Hardware fittings and accent components. Specify recycled brass where available.
Low-Carbon Iron	High ductility, machinable. Corrodes rapidly without coating.	Structural and decorative components. Always apply protective coating. Recyclable.

Table 3 — *Principal metals and alloys in furniture production*

4.1.1 Textiles, Foams, and Finishes

Upholstery Textiles

Figure 5 *Commercial Contract Grade Upholstery Fabric* (Source: https://www.decorativefabricsdirect.com/Contract-Upholstery-Fabric-and-Drapery-Fabric-s/390.htm?srsltid=AfmBOor7_cMlMw4zCeAvqugulEDIuEsZVPGuWkbeg9nZEFIloQs96mln)

Fabric selection has significant environmental implications as well as aesthetic and performance consequences. Upholstery fabrics should be robust, dimensionally stable, and rated for the intended use intensity. The Martindale Rub Test provides the standard durability benchmark:

Use Context	Minimum Martindale Rating
Scatter cushions / curtains	< 10,000 (not suitable for seats)
General domestic use	15,000 – 25,000
High-use domestic (children, pets)	25,000 – 30,000

Commercial (restaurant, hotel)	> 30,000

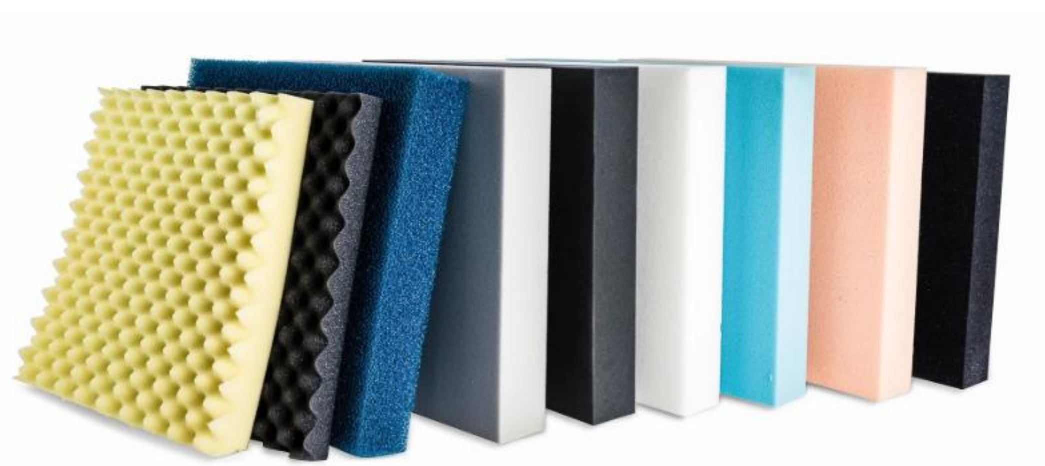
Table 4 — Martindale rub test ratings by use context

The table below summarises the principal upholstery fibres from an environmental perspective:

Fibre	Environmental Profile	Notes for Sustainable Specification
Linen / Hemp	Low water use; plant-based; small ecological footprint.	Excellent choice for sustainable upholstery. Inherently robust with natural stretch.
Cotton	High water use; energy-intensive; supply chain human rights risks.	Specify Fairtrade certified. Avoid conventional cotton unless fully traceable.
Wool	Natural, biodegradable; naturally fire-resistant.	Source from New Zealand or Australia for verified animal welfare. No FR chemical treatment needed.
Viscose	Wood-pulp cellulose; chemical-heavy production.	Good drape; more affordable than pure naturals. Choose viscose blends with natural fibres.
Recycled Polyester	Oil-derived; lower impact than virgin polyester.	Good for commercial-grade durability. Prefer recycled content. Avoid virgin polyester.
Leather / Suede	Durable, long lifespan. Ethical concerns if not a meat by-product.	Prioritise vintage or by-product leather. High longevity reduces replacement frequency.

Table 5 — Upholstery fibres: environmental profiles and specification guidance

Cushioning and Foam



Foam selection must balance comfort, durability, and environmental profile. The two primary considerations are density and firmness:

- High-density foam provides superior support and longevity and is preferred for frequently used furniture.
- Lower-density foam is suitable for decorative or occasional-use seating.
- A 2-inch thickness is typically optimal for dining chair cushions; deeper lounge seating may use 4-inch foam.

Trainer tip

When specifying foam, request low-VOC and CertiPUR-US® or OEKO-TEX® certified products to minimise chemical emissions and support indoor air quality.

Surface Finishes and Adhesives

Figure 6 *Woodworking glues and adhesives used in furniture production* (Source: https://www.woodcraft.com/blogs/sanding-finishing/complete-guide-to-woodworking-glues?srsltid=AfmBOoou8uQMhyLx6Zua8vnZoPpzm-DIFC12nNwnLjXxflYyLaHI8yWs)

Furniture adhesives must balance performance, durability, and environmental compliance. The industry has moved from solvent-based systems toward two preferred alternatives:

Waterborne dispersion adhesives: Environmentally friendly, solvent-free. Cured by water evaporation. Can be applied by spray, roll coating, or beads. Most common application method is spray.

Hot melt adhesives: Applied as thermoplastics using heat; solvent-free. Cured on cooling. Applied predominantly by spray in furniture upholstery.

Key sustainability certifications for adhesives and finishes include:

- OEKO-TEX Eco Passport — guarantees no restricted substances
- GREENGUARD Gold — low chemical emissions; safe for schools and healthcare
- TUV Rheinland — safety and sustainability assessment

4.1.3 How to Determine If Furniture Materials Are Sustainable?

Determining the sustainability of furniture materials requires evaluation across material sourcing, certifications, production processes, lifespan, and recycling potential. The following certifications provide the most direct and reliable basis:

Certification	Scope and Significance
FSC (Forest Stewardship Council)	Ensures timber comes from legally and sustainably managed forests. Chain-of-custody certification required for full product traceability.
PEFC	Similar to FSC; focuses on sustainable management of small-scale forest farms. Wide global certified forest area.
BIFMA LEVEL®	For office furniture: assesses environmental impact, social responsibility, and health. Silver, Gold, Platinum tiers.
LEED Certification	Building assessment system; its material environmental requirements can indirectly validate furniture material sustainability.
China Ten-Ring Certification	Covers formaldehyde emission, VOC control, and resource utilisation for products targeting Asian markets.

Table 6 — Environmental certifications for furniture materials

4.2.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a standardised technique for assessing the environmental impacts of consecutive and interlinked stages of a product's life: from raw material extraction, through materials processing, manufacturing, distribution, product use, repair and maintenance, to end-of-life management including recycling and recovery. The process is governed by the ISO 14000 suite of international standards.

LCA differs from related tools in its scope and rigour:

Assessment Type	Scope
Product Carbon Footprint (PCF)	Measures greenhouse gas emissions only, from production to disposal.
Corporate Carbon Footprint (CCF)	Measures total GHG emissions of an entire company including operations, supply chain, and employees.
Life Cycle Assessment (LCA)	Assesses the full environmental impact of a product, including additional factors such as water use, land use, and social impact.

Table 7 — PCF, CCF, and LCA compared

The Five Key Life Cycle Stages:

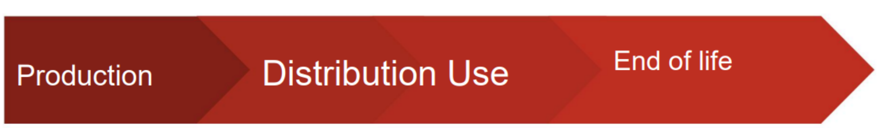
1. Raw material extraction: sourcing, mining, logging, farming. Environmental impacts include deforestation, water consumption, and energy use.

2. Design and production: processing raw materials into finished products. Significant energy and water inputs; releases GHG emissions.

3. Packaging and distribution: preparation for transport and delivery. Emissions from packaging materials and logistics fuel.

4. Use and maintenance: consumer use and upkeep. Energy and resource consumption may accumulate significantly over the product's lifespan..

5. End of life: disposal, recycling, or recovery. Emission sources include methane from landfill, energy for recycling, and pollutants from incineration.



4.2.2 The Life Cycle Assessment Stages

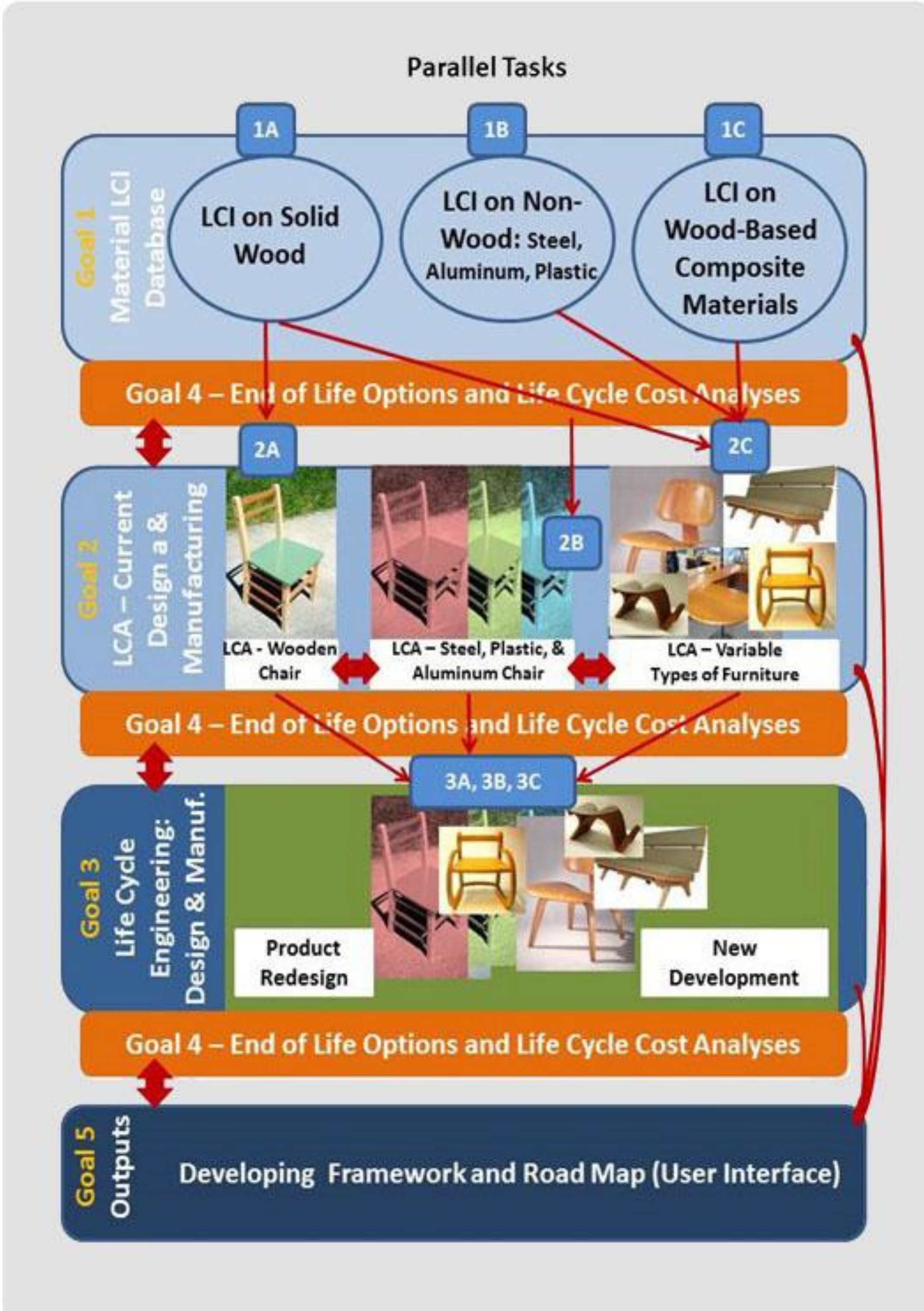


Figure 3: Illustration of LCA of furniture products (Source: https://ag.purdue.edu/department/fnr/lab-sites/woodresearch/lca-on-furniture.html)

A full LCA follows four key stages as defined by ISO 14040 and ISO 14044:

Stage 1: Goal and Scope Definition

The goal and scope define why the assessment is being performed and what it covers. Key technical elements include:

- Functional Unit: the precise, quantified measure of the product's function used as the reference baseline for all comparisons.
- System Boundaries: defines which life cycle processes and stages are included and excluded, along with stated assumptions and limitations.
- Allocation Methods: rules for partitioning environmental loads when several products or functions share the same process.
- Impact Categories: the environmental impact dimensions to be assessed (e.g. global warming, human toxicity, water depletion).

Stage 2: Life Cycle Inventory Analysis (LCI)

The LCI stage involves gathering all quantified inputs and outputs across the product system: energy, water, raw materials, and releases to air, land, and water. Data is collected and related to the functional unit defined in Stage 1.

Stage 3: Life Cycle Impact Assessment (LCIA)

Once inventory data is assembled, environmental impacts are evaluated across selected categories. For furniture products, typical categories include:

- Raw materials (timber, board, plastics, textiles, metal)
- Utilities (electricity, gas, water)
- Transport (inbound materials and outbound products)
- Waste management
- Packaging

Results are expressed in a common unit of kg CO_2 equivalent (kgCO_2e) for climate-related categories, enabling comparison across processes and products.

Stage 4: Interpretation

Life cycle interpretation identifies, quantifies, and evaluates the results of the impact assessment. The output is a set of conclusions and recommendations communicated in a fair, complete, and accurate manner.

4.2.3 LCA Tools and Software

Conducting a full LCA manually is complex and time-consuming. A number of software tools support data collection, modelling, and reporting:

Tool	Description
SimaPro	Widely used for academic and commercial LCAs. Extensive database.
OpenLCA	Open-source tool with flexible modelling. No licence cost.
GaBi	Comprehensive software with robust industry databases.
Ecoinvent	Key life cycle inventory database used alongside modelling tools.
Plan Be Eco	Online platform supporting carbon footprint calculations for SMEs.

Table 8 — LCA software tools

4.2.4 Why Conduct an LCA?

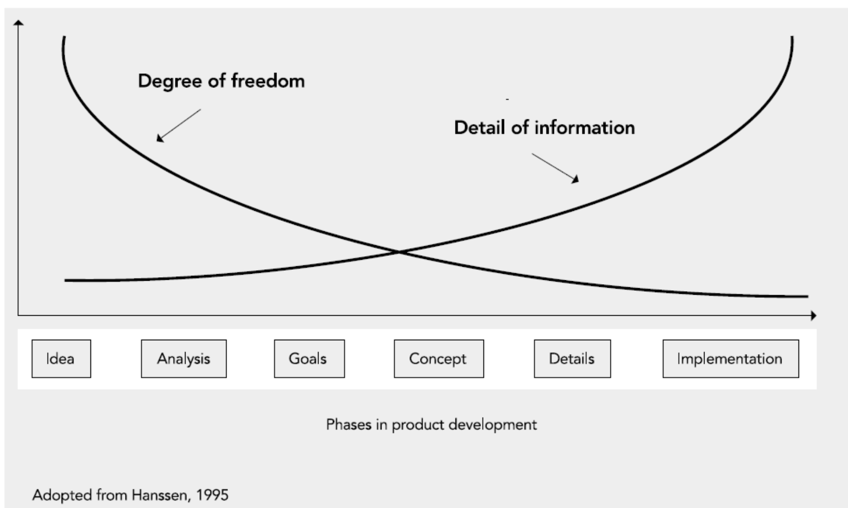


Figure 8: *Relationship between the designers' degree of freedom and the level of information*

LCA provides multiple benefits for furniture businesses:

- Identifies environmental hotspots to target reductions where they will have the greatest impact.
- Supports regulatory compliance with CSRD, CBAM, EUDR, and the forthcoming EU Digital Product Passport.
- Informs design, sourcing, and production decisions with objective environmental data.
- Enhances brand credibility through transparent sustainability reporting.
- Provides the data needed to set science-based emissions reduction targets.

- Drives operational efficiency by identifying resource waste across the value chain.

Info

The EU Digital Product Passport (DPP) will require companies to provide detailed environmental impact information for products. Phased implementation is expected between 2026–2030. Having an LCA in place now positions SMEs to meet this requirement ahead of the deadline.

4.3.1 Levels of LCA Sophistication

LCA exists on a continuum of increasing methodological rigour. Three levels are commonly distinguished:

Level	Description
Conceptual LCA (Life Cycle Thinking)	Mostly qualitative. Identifies the life cycle stages and potential impacts of greatest significance. Useful for design briefs and policy discussions. Not suitable for external claims.
Simplified LCA	Comprehensive screening assessment covering the whole life cycle using generic data, standard modules for transport and energy, and focused assessment of the most significant stages. Suitable for internal decision-making and, if properly reported, for some external uses.
Detailed LCA	Full quantitative assessment based on site-specific data, complete inventory, and rigorous impact assessment. Time- and resource-intensive. Required for public environmental claims and EPDs.

Table 9 — Levels of LCA sophistication

For furniture SMEs and VET learners, the Simplified LCA approach provides the best balance between practical feasibility and methodological rigour.

4.3.2 Simplified LCA: Five-Step Process

The following five-step process guides learners through a simplified LCA of outdoor chairs made from different materials: bamboo, oak wood, metal, and plastic. The functional unit for this comparison is a set of six outdoor terrace chairs used over twenty years.

	Level of detail in LCA			
Application	Conceptual	Simplified	Detailed	Comments
Design for Environment	**x**	x		No formal links to LCA
Product development	x	**x**	x	Large variation in sophistication
Product improvement		x		Often based on already existing products
Environmental claims (ISO type II-labelling)	**x**			Seldom based on LCA
Ecolabelling (ISO type I-labelling)	x			Only criteria development requires an LCA
Environmental declaration (ISO type III-labelling)			x	Inventory and/or impact assessment
Organisation marketing		**x**	x	Inclusion of LCA in environmental reporting
Strategic planning	**x**	**x**		Gradual development of LCA knowledge
Green procurement	x	**x**		LCA not as detailed as in ecolabelling
Deposit/refund schemes		x		Reduced number of parameters in the LCA is often sufficient
Environmental ("green") taxes		x		Reduced number of parameters in the LCA is often sufficient
Choice between packaging systems	x		**x**	Detailed inventory, Scope disputed LCA results not the only information

Table 10: Level of detail in some applications of LCA. "x" in bold indicates the most frequently used level.

Step 1: Define the Goal and Scope

Establish the purpose of the assessment: to compare the environmental performance of outdoor chairs manufactured from different materials. Define the functional unit precisely and set system boundaries covering raw material acquisition, manufacturing, transportation, and end-of-life management.

Key concept

The functional unit is the precise, quantified measure of the function the product provides. It acts as the reference baseline, ensuring environmental impacts are measured on a fair, comparable basis. In this exercise: a set of six outdoor terrace chairs used over 20 years.

Step 2: Collect Life Cycle Inventory Data

Gather information for each chair type across the following parameters:

- Materials (type and quantity)
- Energy consumption
- Transport distances and modes
- Packaging
- Waste generation
- End-of-life treatment

Step 3: Build a Simple Inventory Table

Compile the data into inventory tables for each material type:

Parameter	Oak Chair	Bamboo Chair
Primary material	0.1 m³ oak wood	0.1 m³ bamboo
Electricity	2 kWh	1.5 kWh
Packaging	Cardboard	7 m² plastic film
Transport	300 km truck	20,000 km ship + 300 km truck
End-of-life	Incineration	Incineration

Table 11 — LCI data: oak and bamboo chairs

Figure 9: *Types of chair materials*

Parameter	Metal Chair	Plastic Chair
Primary material	4.5 kg iron	2.5 kg plastic
Surface treatment	1.1 m² powder coating	Injection moulding: 2.5 kg
Electricity	3 kWh	—
Packaging	5 m² plastic film	—
Transport	800 km truck	500 km truck

End-of-life	Recycling	Recycling

Table 12 — LCI data: metal and plastic chairs

Step 4: Calculate Key Environmental Indicators

Three key indicators are calculated for each chair type using simplified emission factors:

Material / Process	Simplified Emission Factor
Hardwood	0.5 kg CO_2e / kg
Bamboo	0.3 kg CO_2e / kg
Steel / Iron	2.0 kg CO_2e / kg
Plastic	2.5 kg CO_2e / kg
Electricity	0.4 kg CO_2e / kWh
Truck transport	0.1 kg CO_2e / tonne·km
Ship transport	0.01 kg CO_2e / tonne·km

Table 13 — Simplified emission factors for carbon footprint calculation

Example: Renewable Material Content — Oak Chair

Oak wood: 12 kg (renewable) | Steel screws: 0.5 kg (not renewable) | Varnish: 0.2 kg (not renewable) Total mass: 12.7 kg | Renewable mass: 12 kg Renewable Material Content = (12 ÷ 12.7) × 100 = 94.5%

Example: End-of-Life Recyclability — Metal Chair

Steel: 4.5 kg (recyclable) | Powder coating: 0.2 kg (not recyclable) Total mass: 4.7 kg | Recyclable mass: 4.5 kg Recyclability = (4.5 ÷ 4.7) × 100 = 95.7%

Step 5: Prepare an Environmental Fact Sheet

Summarise results in a comparative environmental fact sheet. Score each indicator on a simple scale (1–5) to produce a rapid comparison:

Chair Type	Carbon Score (1–5)	Renewable Content (1–5)	Recyclability (1–5)	Total
Oak	4	5	3	**12**
Bamboo	4	5	2	**11**
Metal	2	1	5	**8**
Plastic	2	1	4	**7**

Table 14 — Environmental fact sheet: comparative scoring of chair materials

4.4.1 Furniture Carbon Footprint

Although furniture production is often perceived as a low-emission sector, it generates significant greenhouse gas emissions, primarily from electricity consumption, the production of wood-based materials, and transport. Across the supply chain, additional indirect emissions arise from adhesives, varnishes, metal components, and textiles. Growing regulatory requirements — CSRD, EUDR, CBAM — alongside customer and investor expectations are making carbon footprint measurement and reporting essential for furniture manufacturers.

4.4.2 Emission Hotspots in the Furniture Value Chain

Value Chain Stage	Key Emission Sources	Reduction Strategies
Raw material sourcing	Deforestation, raw material transport, energy in sawmills.	Certified wood (FSC, PEFC); local suppliers; recycled materials.
Manufacturing & processing	Energy-intensive machining, finishing, surface treatment.	Renewable energy; water-based coatings; heat recovery; waste minimisation.
Transport & logistics	Fuel combustion — inbound materials and outbound products.	Route optimisation; shared logistics; low-emission vehicles; last-mile planning.
Packaging	Production of cardboard and plastic films.	Recycled packaging; reusable packaging; reduce plastic and Styrofoam.
Product use & end of life	Disposal energy; methane from landfill; incineration.	Design for durability, repairability, and recyclability. Extend product lifespan.

Table 15 — Emission hotspots and reduction strategies in the furniture value chain

4.4.3 How to Calculate the Carbon Footprint of Furniture

A Product Carbon Footprint (PCF) is calculated in accordance with ISO 14067 or the GHG Protocol methodology. The process involves:

1. Defining system boundaries (cradle-to-gate or cradle-to-grave).
2. Collecting data on energy, fuel, raw material use, transport, and waste.
3. Applying credible, sector-specific emission factors.
4. Identifying hotspots — the areas with the highest climate impact.
5. Setting a reduction target (e.g. 10% reduction over two years in transport or auxiliary materials).
6. Communicating results in an ESG report or on the company website.
7. Monitoring year over year and updating the decarbonisation strategy.

4.4.4 Industry Examples

The following companies illustrate leading practice in furniture sector decarbonisation:

IKEA

In FY24, IKEA reported a total carbon footprint of 21.3 million tonnes CO_2e — a 5% decrease year-on-year and 28% below the FY16 baseline. Materials account for 52% of the total footprint (cradle-to-gate). The company targets a 50% reduction in material emissions by 2030 versus FY16, supported by 491+ factories using 100% renewable energy.

Flokk

In 2024, 39% of materials used in Flokk products were recycled, with a 2030 target of 40%. In 2023, 72.5% of production waste was recycled. The company provides Environmental Product Declarations (EPDs) for its main products.

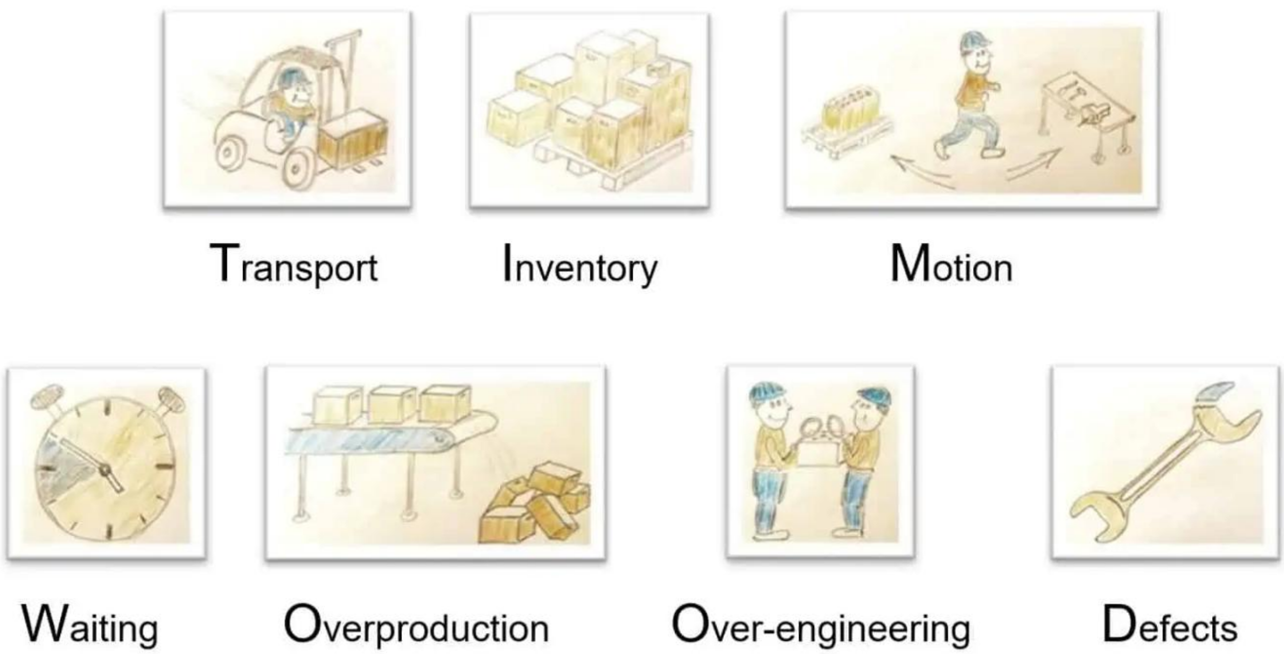
Actiu

First Spanish furniture manufacturer to register its carbon footprint (Scopes 1, 2, and 3) in the MITERD registry. Uses 100% renewable energy; avoided 2,175 tonnes CO_2e between 2022–2023. LEVEL® 2 certification obtained for 59 product lines.

4.5.1 Material Waste in Furniture Manufacturing

Material waste in furniture manufacturing is rarely confined to obvious scrap beside machines. It includes offcuts from cutting operations, rejected finished products, start-up losses, overfill, damaged packaging, excess inventory written off at stocktake, and materials lost between process steps. Since 2020, volatile raw material costs have elevated waste reduction from a background concern to a board-level priority.

4.5.2 Waste Reduction Strategies



Map and Measure Material Flows

Waste reduction begins with understanding how materials actually move through the production process. Start by creating a material balance for one production line or product family: track all raw materials entering the process and compare against finished products, scrap, rework, and unexplained loss. Even small unexplained losses (1–2%) frequently reveal systematic handling errors or undocumented process variation.

Value Stream Mapping

Value stream mapping provides a visual overview of production flows, highlighting unnecessary steps, excess handling, waiting time, and bottlenecks that generate waste. Mapping sessions are most effective when operators, engineers, and planners participate together.

Lean Manufacturing Principles

- Standardised work: reduces variation, errors, and rework; improves first-pass yield.
- Smaller batch sizes: reduce overproduction and limit the scale of losses when defects occur.
- Continuous improvement (Kaizen): small, consistent improvements to material yield accumulate significant gains over time.

Closed Loop Manufacturing

- Segregate waste streams at source to preserve material value for reuse or recycling.
- Use baling, compacting, granulating, or shredding equipment to prepare materials for re-entry.
- Review order unit sizes with suppliers to align delivery formats with production batch requirements.

4.5.3 Digital Tools for Waste Reduction

Digital tools change the dynamic of waste management by providing real-time visibility into material flows:

- MES/ERP integration: compares planned vs actual material usage in real time; variances become visible immediately.
- Automated cutting and nesting software: optimises material layout before the first cut, minimising offcuts and improving yield consistency.
- Real-time dashboards: make waste, yield, and efficiency visible on the shop floor, reinforcing accountability without management pressure.

4.5.4 Equipment Maintenance and Process Stability

Even well-designed processes generate waste when equipment performance is inconsistent. Worn tools, misalignment, temperature drift, and poor calibration manifest as scrap, rework, and quality variation. Preventative and condition-based maintenance — using vibration analysis, thermal inspection, and sensor feedback — stabilises the manufacturing process and prevents the sudden waste spikes that accompany breakdowns.

4.5.5 Engaging People in Waste Reduction

Long-term success depends on the people running the production process every day. Training should focus on recognising different forms of waste, understanding their commercial and operational impact, and knowing what to do when waste increases. Visual management tools — scrap boards, trend charts, and clearly defined waste streams — make performance tangible. Regular feedback and simple suggestion schemes reinforce continuous improvement.

Trainer tip

A Kaizen event focused specifically on material yield — run with mixed operator, engineering, and planning teams over one or two days — consistently identifies waste that teams have learned to tolerate and generates a prioritised improvement action list.

5. Activities and Exercises

Activity 5.1 — Material Sustainability Audit

Field	Detail
Activity Number	Activity 2.1
Activity Title	Material sustainability audit of a furniture product
Type	Small group (5–10 learners)
Duration	90 minutes
Learning Outcomes Addressed	LO 1
Materials Needed	Sample furniture product (or product photograph and specification sheet), FSC/PEFC certification reference guide, Material selection scoring worksheet
Instructions	1. Select a furniture product provided by the trainer or from your host SME. 2. List all materials used (timber species, engineered boards, metal, fabric, adhesive, finish). 3. Research each material's environmental credentials: sourcing certification, recyclability, hazardous substance content. 4. Score each material using the provided framework (1–5 for environmental performance). 5. Identify the two materials with the weakest environmental score and propose alternatives. 6. Present findings to the group in a 5-minute summary.
Expected Output	Completed material scoring worksheet; short written or verbal summary identifying the two highest-impact materials and proposed alternatives.
Trainer Notes	Encourage learners to check FSC/PEFC chain-of-custody documentation if the SME holds certification. Common difficulties: learners confuse product label certification with factory certification.
Assessment Link	Annex B, Criterion 1: Material identification and environmental evaluation.

Table 16 — Activity block: Activity 2.1

oak

Parameter	Value
Oak wood	0.1 m³
Electricity	2 kWh
Packaging	Cardboard
Transport	300 km by truck
End-of-life	Incineration

Parameter	Value
Bamboo	0.1 m³
Electricity	1.5 kWh
Packaging	7 m² plastic film
Transport	20,000 km by ship + 300 km truck
End-of-life	Incineration

bamboo

Parameter	Value
Iron	4.5 kg
Powder coating	1.1 m²
Electricity	3 kWh
Transport	800 km truck
Packaging	5 m² plastic film
End-of-life	Recycling

metal

Parameter	Value
Plastic	2.5 kg
Injection moulding	2.5 kg
Transport	500 km truck
End-of-life	Recycling

plastic

Figure 10 *Chair parameter and Value*

Activity 5.2 — Simplified LCA of Outdoor Chairs

Field	Detail
Activity Number	Activity 2.2
Activity Title	Simplified LCA of outdoor chairs — material comparison
Type	Individual or pair
Duration	120 minutes
Learning Outcomes Addressed	LO 2, LO 3

Materials Needed	LCI data tables (see Section 4.2), Emission factor reference sheet, Environmental fact sheet template
Instructions	1. Review the LCI data tables for oak, bamboo, metal, and plastic outdoor chairs. 2. Calculate the carbon footprint for each chair using the provided emission factors. 3. Calculate the renewable material content and end-of-life recyclability for each chair. 4. Score each indicator on a 1–5 scale. 5. Complete the environmental fact sheet comparing all four chairs. 6. Write a 150-word recommendation identifying which chair performs best environmentally and why.
Expected Output	Completed environmental fact sheet with calculations; 150-word written recommendation.
Trainer Notes	Learners often struggle with unit conversion (tkm for transport). Walk through the first calculation together. Emphasise that the bamboo chair's high transport distance significantly affects its score.
Assessment Link	Annex B, Criterion 2: LCA methodology and environmental fact sheet preparation.

Table 17 — Activity block: Activity 2.2

Activity 5.3 — Company-Based WBL Task: Waste Walk

Field	Detail
Activity Number	Activity 2.3
Activity Title	Production floor waste walk and material balance
Type	Company-based WBL task (individual)
Duration	2–3 hours on-site; 1 hour reporting
Learning Outcomes Addressed	LO 4, LO 5
Materials Needed	Waste walk observation form, Material balance template, Camera or mobile device for documentation
Instructions	1. Arrange access to the production floor with your workplace supervisor. 2. Walk through the production process from raw material intake to finished product dispatch. 3. At each station, record: type of material used, visible waste generated, waste handling method, and any obvious inefficiencies. 4. Using the observation data, complete a simple material balance for one product line. 5. Identify the three largest sources of material waste. 6. Propose one improvement measure for each source and estimate the potential material saving.
Expected Output	Completed waste walk observation form; simple material balance table; written proposal with three improvement measures.

Workplace Supervisor Brief	Please give the learner access to one production line or product area for 2–3 hours. Allow them to observe, ask questions, and photograph waste streams (no commercially sensitive areas).
Learner Reflection Prompt	What surprised you most about the types and quantities of waste in the process? What one change would have the most significant impact and why?
Assessment Link	Annex B, Criterion 3: Waste identification and improvement proposal.

Table 18 — Activity block: Activity 2.3 (Company-based WBL task)

6. Assessment Criteria

The following competency descriptors are linked to the five learning outcomes of Module II. They form the basis for the assessment rubric provided in Annex B.

LO Ref	Not Yet Competent	Competent	Highly Competent
LO 1	Identifies some materials but cannot evaluate environmental credentials.	Identifies all major material categories and correctly evaluates their FSC/PEFC certification status and key environmental impacts.	Applies a systematic material selection framework, compares alternatives quantitatively, and makes evidence-based sourcing recommendations.
LO 2	Describes LCA in general terms but cannot define the four stages correctly.	Defines all four LCA stages, explains functional unit and system boundaries, and correctly interprets a given LCA report.	Critiques the scope and assumptions of an LCA report and identifies how different boundary choices would affect results.
LO 3	Completes an inventory table with significant gaps or errors.	Completes a simplified LCA inventory, calculates carbon footprint and recyclability indicators correctly, and presents results in a structured fact sheet.	Critically evaluates the limitations of the simplified approach and identifies what additional data would improve reliability.

LO 4	Identifies some emission sources but cannot calculate a footprint.	Identifies all major emission hotspots in the furniture value chain and calculates a simplified product carbon footprint using correct methodology.	Proposes a prioritised decarbonisation plan with quantified targets for each stage of the value chain.
LO 5	Identifies waste on the shop floor but cannot propose structured improvement measures.	Identifies the three main waste sources in a production process, applies lean principles to propose reduction measures, and estimates potential material saving.	Designs a complete waste reduction programme including measurement system, lean tools, digital tracking, and people engagement strategy.

Table 19 — Assessment competency descriptors by learning outcome

7. Trainer Guidance Notes

7.1 Dellvery Approach

Module II is designed for blended delivery combining trainer-led sessions, self-directed reading, and work-based learning activities. The recommended delivery sequence is:

1. Introduce Unit 4.1 (Materials) with physical samples where possible. SME partner visits to materials stores are highly effective.
2. Use Unit 4.2 (LCA Introduction) as the conceptual anchor before introducing the hands-on calculation exercise in Unit 3.
3. Conduct Activity 4.3 (Simplified LCA) in class before the WBL waste walk to build learner confidence with methodology.
4. Schedule Activity 4.4 (WBL Waste Walk) during workplace placement, briefing the workplace supervisor in advance.
5. Use industry case studies (IKEA, Flokk, Actiu in Unit 4) to ground abstract concepts in current commercial practice.

7.2 Common Learner Difficulties

Common Difficulty	Suggested Trainer Response
Confusion between FSC product label and FSC chain-of-custody certification	Use a physical product to demonstrate the label and explain that the factory holding the CoC certificate is distinct from the forest certification.

Unit conversion errors in LCA calculations (tkm)	Walk through the first transport calculation step-by-step. Provide a worked example prominently in the activity sheet.
Difficulty interpreting LCA results — 'which is better?'	Emphasise that LCA results depend on the question asked. A product with a low carbon footprint may have high water use. Use the scoring table approach.
Underestimating indirect waste (not just scrap bins)	Use the material balance exercise to reveal losses that are not visible at any single workstation. The shock of the unexplained 1–2% loss is a powerful teaching moment.

Table 20 — Common learner difficulties and trainer responses

References and further reading

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Figure reference

Figure 1. ESI. (2026). Local training in Albania [Photograph].

Figure 2. EverWoody. (n.d.). Solid wood or engineered wood? Anatomy of composite wood products. https://www.everwoody.com/solid-wood-or-engineered-wood/

Figure 3. Cabinfield. (n.d.). Different types of wood for furniture: Picture guide. https://www.cabinfield.com/blog/different-types-of-wood-for-furniture-picture-guide/

Figure 4. ESI. (2026). Metal shelf unit produced at Opinga Craft workshop [Photograph].

Figure 5. Decorative Fabrics Direct. (n.d.). Commercial contract grade upholstery fabric. https://www.decorativefabricsdirect.com/Contract-Upholstery-Fabric-and-Drapery-Fabric-s/390.htm

Figure 6. Woodcraft. (n.d.). Complete guide to woodworking glues. https://www.woodcraft.com/blogs/sanding-finishing/complete-guide-to-woodworking-glues

Figure 7. Purdue University, Department of Forestry and Natural Resources. (n.d.). Life cycle assessment (LCA) on furniture. https://ag.purdue.edu/department/fnr/lab-sites/woodresearch/lca-on-furniture.html

Annex A: Learner Worksheet — Simplified LCA Exercise

Name: ______________________________ Date: ____________ Workplace/SME: ______________________________

Part A — Inventory Table Completion

Using the data provided by your trainer, complete the life cycle inventory table for your assigned chair type:

Parameter	Value (your chair type)
Primary material (type and quantity)	
Electricity (kWh)	
Packaging (type and quantity)	
Transport (mode and distance)	
End-of-life treatment	

Learner Worksheet Table A — LCI data entry

Part B — Carbon Footprint Calculation

Show your calculation for the carbon footprint of one chair (use the emission factors from Table 12):

Carbon footprint calculation:

Total carbon footprint (kg CO_2e):

Part C — Environmental Indicators

Calculate and record:

Indicator	Result
Renewable Material Content (%)	
End-of-Life Recyclability (%)	
Overall Environmental Score (1–5)	

Part D — Recommendation

In 100–150 words, explain which chair material performs best environmentally and what the main trade-offs are:

Annex B: Assessment Rubric

Assessor:____Learner: _____________

Date: ____

Criterion	Competent (pass)	Highly Competent (merit)	Assessor Comment	Score
1. Material identification & evaluation	Correctly identifies material categories and evaluates environmental credentials using appropriate certifications.	Applies systematic scoring framework; proposes evidence-based alternatives with quantified improvement.		/ 10
2. LCA methodology & fact sheet	Completes LCI table and fact sheet accurately; correctly calculates carbon, renewable content, and recyclability indicators.	Critically evaluates methodology limitations and identifies data gaps that would improve reliability.		/ 10
3. Waste identification & improvement	Identifies three main waste sources and proposes a structured reduction measure for each.	Quantifies potential saving and designs a monitoring approach to track progress.		/ 10
Total	Pass: 18 / 30	Merit: 24 / 30		**/ 30**

Annex B — Assessment rubric

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Module III

Optimization to Make Furniture More Circular

Item	Description
Document type	CBF Toolkit — Work-Based Learning Module
Module	Module III
Title	Optimization to Make Furniture More Circular
Programme	Erasmus+ CB-VET
Project	SUSFUR — Promoting Sustainable Furniture Production in the Western Balkan Through Strengthening the Linkages between Business Sector and VET Provider
Project number	101183370
Sector	Furniture manufacturing — circular economy
Main contributors	WICA and Merceza, with inputs from project partners
Status	Final approved version — cleared for publication

This module was developed with the support of the Erasmus+ program of the European Union. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors

Table of Contents

1. Module overview

1.1 Learning context and purpose

This module focuses on practical optimization strategies that furniture SMEs can use to make products, processes, and business models more circular. In a circular economy context, optimization means maximizing product and material value while minimizing waste, unnecessary resource use, production inefficiencies, and premature product disposal.

The module builds on circular design and sustainable production by translating these principles into workplace-oriented decisions. Learners explore how furniture companies can optimize product design, material selection, production processes, repair and refurbishment systems, and end-of-life pathways. The emphasis is not only on reducing costs, but also on preserving value across the product life cycle.

For furniture SMEs in the Western Balkans, circular optimization is particularly relevant because many improvements can be introduced gradually and without major investment. Examples include improving cutting efficiency, reducing offcuts, standardising components, using reclaimed or recycled materials, designing products for repair, and creating take-back or refurbishment opportunities.

Key concept: Circular optimization means using design, materials, production processes, and business models more intelligently so that furniture products stay in use longer, waste is reduced, and value is retained across multiple life cycles.

1.2 Target audience

This module is designed for VET learners, early-career professionals, furniture production students, workshop technicians, production planners, designers, and SME staff involved in product development, production, quality control, sustainability, and business development. It also supports VET trainers, WBL coordinators, and workplace mentors who need practical tools to connect circular economy learning with real furniture production environments.

1.3 Delivery format

The module is designed for work-based learning delivery. Learners should work with real or simulated furniture products, production data, bills of materials, cutting lists, material samples, workshop observations, and end-of-life scenarios. The module combines short theoretical inputs with hands-on tasks. Learners analyse an existing product or process, identify inefficiencies, propose optimization measures, and develop either a physical prototype, a conceptual prototype, or a circular business model improvement proposal.

1.4 Scope, content focus, and duration

The module covers five main areas:

1. Introduction to optimization in circular economy.
2. Design, material, production, and end-of-life optimization.
3. Circular Business Model Canvas and circular value creation.
4. Circular business models and strategies for furniture SMEs.

5. WBL application, prototype development, and European best practices.

Recommended duration: 2 training days, 3-4 school hours per day, total 6-8 school hours. The module can also be expanded into a longer WBL assignment if learners develop and test prototypes in a company, laboratory, or artisan workshop.

1.5 Recommended two-day timetable

Day	Focus	Suggested activities	Outputs
Day 1	Optimization foundations and technical diagnosis	Short input on circular optimization; product/process inefficiency scan; material and production optimization exercise	Optimization diagnosis and improvement list
Day 2	Business model, WBL prototype, and implementation planning	CBMC exercise; circular business model comparison; prototype concept; action plan	CBMC, prototype proposal, and SME action plan

Table 1 — Recommended delivery sequence

1.6 Prerequisites

- Basic familiarity with common furniture materials and processes, including wood, wood-based panels, metals, textiles, coatings, assembly, and finishing.
- Ability to read simple product information such as sketches, bills of materials, cutting lists, or workshop process descriptions.
- Basic understanding of circular economy concepts, including durability, repairability, reuse, refurbishment, and recycling.

1.7 Expected learning outputs

- A circular optimization diagnosis for an existing furniture product or process.
- A list of identified inefficiencies and practical improvement opportunities.
- An optimized product or process concept supported by simple technical reasoning.
- A basic Circular Business Model Canvas for a furniture SME case.
- A prototype concept or physical prototype proposal.
- A short action plan for implementation in a furniture SME.

2. Learning outcomes

The learning outcomes follow an action verb + condition + standard format and are designed to be measurable in classroom, workshop, and company-based WBL settings.

Learning outcome	Competency statement
LO1 — Identify circular optimization opportunities	By the end of this module, learners will be able to IDENTIFY circular optimization opportunities in a furniture product or production process, given a workplace scenario, by detecting at least five inefficiencies related to design, material use, production, repairability, or end-of-life planning.

LO2 — Analyse material and production efficiency	By the end of this module, learners will be able to ANALYSE material and production efficiency, given a bill of materials, cutting list, or workshop example, by identifying sources of waste and proposing at least three practical measures to reduce material loss, rework, or unnecessary resource use.
LO3 — Apply circular design and process optimization strategies	By the end of this module, learners will be able to APPLY circular optimization strategies to a furniture product, given an existing design or product concept, by proposing improvements related to modularity, repairability, disassembly, material efficiency, and production workflow.
LO4 — Use the Circular Business Model Canvas	By the end of this module, learners will be able to USE the Circular Business Model Canvas, given a furniture SME case, by mapping the value proposition, customer relationships, revenue streams, key activities, resources, partnerships, and circular value-retention mechanisms.
LO5 — Evaluate circular business model options	By the end of this module, learners will be able to EVALUATE circular business model options for furniture SMEs, given a practical scenario, by comparing at least three models such as Furniture-as-a-Service, refurbishment, take-back schemes, modular furniture, and material efficiency platforms.
LO6 — Develop a WBL-based circular prototype or optimization proposal	By the end of this module, learners will be able to DEVELOP a prototype concept or optimization proposal, given a real or simulated workplace challenge, by presenting technical improvements, expected circular benefits, and a basic business model rationale.

***Table 2** — Learning outcomes for Module III*

3. WBL context and sector relevance

3.1 Why optimization is workplace-relevant for furniture SMEs

Furniture SMEs often operate with limited margins, small batches, variable customer requirements, and strong pressure to deliver high-quality products quickly. These conditions make optimization highly relevant. Circular optimization helps SMEs reduce unnecessary material use, reduce waste, improve product lifetime, and create new value from repair, refurbishment, and reuse.

In many workshops, circular opportunities are hidden inside routine decisions: how panels are cut, how components are joined, how defective pieces are handled, whether offcuts are reused, how spare parts are stored, and whether the company has a clear plan for returned or damaged products. This module turns these everyday decisions into structured learning tasks.

3.2 How optimization connects to everyday SME workflows

Workflow area	Typical SME decision	Circular optimization opportunity
Product design	Choice of structure, modules, and joints	Simplify the product, reduce unnecessary parts, make components replaceable, and support disassembly.
Material procurement	Selection of boards, wood, textiles, finishes, and hardware	Prioritise durable, repairable, lower-waste, recoverable, recycled, or certified materials where feasible.
Cutting and machining	Cutting plans, nesting, drilling, routing, and CNC setup	Improve yield, reduce offcuts, standardise dimensions, and reuse production leftovers.

Assembly	Use of adhesives, fasteners, brackets, and fittings	Use reversible joints where possible and reduce fastener variety to speed repair and disassembly.
Finishing	Choice of coating and surface treatment	Select finishes that support durability, refinishing, lower emissions, and safe material recovery.
After-sales service	Repair, warranty, and customer complaints	Design for faster repair, spare parts availability, maintenance instructions, and refurbishment.
End-of-life	Returned, damaged, or obsolete furniture	Plan take-back, reuse, refurbishment, component harvesting, or recycling routes.

***Table 3** — Optimization touchpoints in furniture SME workflows*

Trainer tip: Ask learners to start from a product already produced by a local SME. Optimization becomes easier when learners can see the material, joints, production steps, and waste points directly.

3.3 Relevance for Western Balkan SMEs

The Western Balkan furniture sector includes many SMEs and artisan-based producers that rely on practical production knowledge, flexible customer orders, and local networks. Circular optimization can support these companies because it does not always require advanced technology. Small changes can create visible benefits: better material yield, fewer defective components, lower waste-disposal needs, easier repairs, and improved competitiveness in markets where sustainability expectations are increasing.

3.4 Role of VET providers and workplace mentors

VET providers and workplace mentors play an important role in helping learners translate circular economy principles into practical production improvements. Trainers should guide learners to use evidence from the workplace: material flows, workshop observations, bills of materials, defects, repair cases, and customer feedback. Workplace mentors can support the module by providing access to a product sample, process description, or common repair problem.

4. Content units

4.1 Introduction to optimization in circular economy

Optimization in a circular context means maximizing value while minimizing resource use and waste. It involves improving product design, material selection, production processes, and end-of-life planning. Unlike traditional efficiency, circular optimization focuses on keeping products, components, and materials in use for as long as possible.

In a conventional linear model, optimization is often limited to reducing production cost or increasing output. In a circular model, optimization also asks whether the product can last longer, be repaired faster, be refurbished economically, be disassembled safely, and retain value after the first use cycle.

Info: Traditional efficiency asks: How can we produce faster and cheaper? Circular optimization also asks: How can we keep value in the product for longer and reduce waste across the life cycle?

4.1.1 Identifying inefficiencies in furniture systems

The optimization process begins with identifying inefficiencies. In furniture production, these can appear at product, material, process, business model, and end-of-life levels. Common inefficiencies include excessive use of raw materials, complex product structures, non-repairable components, inefficient cutting and production processes, and lack of end-of-life planning.

Inefficiency	Circular risk	Possible optimization
Excessive use of raw materials	Higher cost, more waste, and higher environmental burden	Improve cutting plans, reduce unnecessary dimensions, use lighter but durable structures, and reuse offcuts.
Complex product structure	Difficult assembly, repair, disassembly, and refurbishment	Simplify the product structure, standardise parts, and reduce the number of fastener types.
Non-repairable components	Shorter product lifetime and higher replacement rates	Use replaceable parts, accessible joints, and documented spare parts.
Inefficient cutting and machining	Low material yield and high offcut generation	Use nesting, cutting optimisation, standard dimensions, and offcut classification.
High rework or defect rate	Extra labour, extra material use, and production delays	Improve quality checks, work instructions, and process control.
No end-of-life planning	Furniture becomes waste even if parts still have value	Map components to repair, reuse, refurbishment, remanufacturing, or recycling routes.

Table 4 — Common inefficiencies and optimization responses

4.1.2 Indicators for measuring circularity and optimization

To measure circularity, products and processes can be evaluated using simple indicators that are understandable in SME and VET contexts. These indicators do not replace a full life-cycle assessment, but they help learners identify where improvement is possible.

Indicator	What it measures	Example workplace question
Durability	Expected technical and aesthetic lifespan	Will the product remain functional and acceptable after repeated use?
Repairability	Ease of fixing damaged or worn parts	Can a common failure point be repaired using standard tools within a reasonable time?
Disassembly	Ability to separate components without damage	Can the product be taken apart into wood, metal, textile, foam, and plastic streams?
Recyclability	Potential for material recovery	Are materials identifiable and separable enough for recycling?
Material efficiency	Degree of waste minimisation during production	How much of the input material becomes useful product and how much becomes waste?
Refurbishment potential	Ability to restore or upgrade a product for second use	Can surfaces, upholstery, or modules be replaced without replacing the whole product?

Table 5 — Practical circular optimization indicators

4.2 Design, material, production, and end-of-life optimization

Circular optimization should be understood as an end-to-end framework covering design, materials, production, and end-of-life stages. By improving efficiency, reducing waste, and enabling reuse and recovery, these strategies help SMEs enhance sustainability while maintaining product quality and economic value.

Optimization area	Main objective	Typical strategies
Design optimization	Reduce material use and improve lifetime without compromising quality	Simplify product structure, design for disassembly, increase modularity, improve repair access, reduce unnecessary parts.
Materials optimization	Use materials more efficiently and select materials with better circular potential	Reduce waste, use recycled or reclaimed raw materials where feasible, choose durable and separable materials, avoid unnecessary mixed-material bonding.
Production optimization	Improve production flow and reduce waste, defects, and unnecessary resource use	Improve cutting/boring/drilling efficiency, standardise components, optimise workflows, reuse production waste, reduce energy consumption.
End-of-life optimization	Keep products and components in use for longer and recover value after first use	Repair and maintenance services, take-back and refurbishment systems, component reuse, product-service systems such as leasing or sharing.

Table 6 — Four areas of circular optimization

4.2.1 Design optimization

Design optimization focuses on improving the product before it enters production. In circular furniture, design optimization is not only about aesthetics or cost. It is about ensuring that the product can be manufactured efficiently, used for a long time, repaired when needed, and recovered at end-of-life.

- Reduce unnecessary material use without compromising safety, strength, or quality.
- Simplify product structures to reduce assembly complexity and repair difficulty.
- Design for disassembly by using accessible and reversible joining methods where possible.
- Increase modularity so that worn, damaged, or outdated parts can be replaced instead of discarding the whole product.
- Design visible and high-wear parts so they can be refurbished, reupholstered, refinished, or upgraded.

Tip: Design optimization should be tested with a repair or disassembly task. If a part is theoretically replaceable but requires excessive time or specialist tools, the circular benefit may be limited.

Figure 1. *Local training in Albania*; Note. Photograph by WICA (2026).

4.2.2 Materials optimization

Materials optimization aims to reduce material waste and select materials that support circularity. In furniture SMEs, important decisions include panel sizes, board thicknesses, solid wood dimensions, textile use, foam selection, hardware, adhesives, and finishes.

Material issue	Optimization question	Possible action
Panel and board waste	Can the cutting plan be improved?	Use nesting, standard dimensions, and offcut reuse planning.
Offcuts and leftovers	Can leftovers become inputs for another product or component?	Classify offcuts by size/material and create small-part product opportunities.
Mixed materials	Do bonded material combinations block separation?	Avoid permanent bonding where separation or repair is important.
Recycled/reclaimed materials	Can secondary materials be used without reducing quality?	Use reclaimed wood, recycled metal, or recycled-content panels when technically feasible.
Finishes and adhesives	Do chemicals affect repair, indoor quality, or recovery?	Choose finishes that support durability, maintenance, refinishing, and safe handling.

Table 7 — Materials optimization questions

4.2.3 Production optimization

Production optimization focuses on making workshop processes more efficient and circular. It includes reducing waste during cutting and machining, reducing defects and rework, improving workflow, using resources more efficiently, and documenting production knowledge so that circular improvements can be repeated.

- Improve cutting and machining efficiency through better planning and nesting.
- Standardise components and dimensions to reduce complexity and increase reuse possibilities.
- Reduce rework by strengthening quality checks at critical points in the process.

- Reuse production waste where possible, for example for small components, samples, packaging protection, or training materials.
- Reduce energy consumption by planning machine use, maintenance, and batch organisation more effectively.

4.2.4 End-of-life optimization

End-of-life optimization ensures that a product does not automatically become waste after first use. It requires planning for repair, maintenance, refurbishment, take-back, resale, component harvesting, remanufacturing, or recycling. The preferred option is usually the one that keeps the product or component closest to its original function and retains the highest value.

Pathway	What it means	Furniture example
Maintenance	Keeping the product functional through care and minor interventions	Tightening fasteners, cleaning surfaces, replacing glides.
Repair	Restoring a damaged product to function	Replacing a broken hinge, leg, shelf support, or upholstery part.

Reuse	Using the product again with little or no modification	Reselling office chairs or tables after cleaning and inspection.
Refurbishment	Restoring or updating product appearance and function	Reupholstering seating or refinishing wooden surfaces.
Remanufacturing	Rebuilding a product using recovered components	Reusing frames and replacing worn modules for a new product cycle.
Recycling	Recovering material when higher-value loops are not feasible	Separating metal fittings, wood-based materials, plastics, and textiles for material recovery.

Table 8 — End-of-life optimization pathways

4.3 Circular Business Model Canvas

Technical optimization alone is not enough to make furniture more circular. Circularity also requires a business model that explains how value is created, delivered, captured, and retained over time. The Circular Business Model Canvas helps furniture SMEs move from isolated optimization efforts to a more integrated approach where environmental sustainability, operational efficiency, and business competitiveness are addressed together.

In the furniture sector, the Circular Business Model Canvas is especially useful because products can often be physically recovered, repaired, upgraded, and reintroduced into the market. This makes circular strategies technically feasible and potentially economically viable when they are planned properly.

CBMC element	Circular furniture application	Example question for learners
Value proposition	Durable, repairable, modular, low-waste furniture products or services	What circular value does the customer receive?
Customer segments	Households, offices, hotels, schools, public institutions, and B2B buyers	Which customers value durability, repair, leasing, or take-back?
Customer relationships	Maintenance, upgrades, repair support, product information, and take-back communication	How does the company keep contact after the first sale?
Channels	Direct sales, distributors, online platforms, showrooms, public procurement, and service channels	How are circular products and services delivered?
Revenue streams	Sales, leasing, repair fees, refurbishment, resale, spare parts, and service contracts	How can value be captured beyond one-time sales?
Key resources	Materials, skilled labour, design knowledge, workshop capacity, digital records, and spare parts	What resources make circular value possible?
Key activities	Design, production, repair, refurbishment, reverse logistics, quality control, and customer service	What activities must the SME perform repeatedly?
Key partners	Suppliers, recyclers, logistics providers, VET centres, designers, public bodies, and digital platforms	Who supports circular delivery and recovery?
Cost structure	Materials, labour, repair operations, logistics, testing, documentation, and certification	Which costs must be managed for the circular model to work?
Circular value retained	Reduced waste, longer lifetime, second-life products, lower material demand, and stronger customer loyalty	What value is preserved instead of lost?

Table 9 — Circular Business Model Canvas for furniture SMEs

Info: The CBMC helps learners connect technical choices, such as modularity or repairability, with business choices, such as leasing, refurbishment, take-back, and spare-parts services.

4.4 Key circular business models and strategies

To operationalize circular optimization, furniture SMEs can adopt circular business models that enable value retention, resource efficiency, and new revenue streams. These models translate technical improvements into practical and scalable market solutions.

Model / strategy	Description	Implementation notes
Furniture-as-a-Service (FaaS)	Companies provide furniture through rental or leasing models while retaining ownership. This allows manufacturers or service providers to manage maintenance, upgrades, and end-of-life recovery.	Best suited for offices, hotels, schools, public institutions, and temporary spaces where customers value flexibility.
Refurbishment and remanufacturing	Companies extend product lifespan by repairing, upgrading, refinishing, or reupholstering used furniture.	Best suited for products with durable frames, modular parts, or high material value.
Take-back schemes	Manufacturers or retailers collect used products from customers to refurbish, remanufacture, harvest components, or recycle materials.	Requires reverse logistics, product identification, inspection routines, and clear customer communication.
Modular design furniture	Products are designed with interchangeable components, enabling easy repair, upgrading, disassembly, and adaptation.	Useful for furniture with high-wear parts, changing user needs, or repeated refurbishment potential.
Material efficiency and sharing platforms	Companies use sustainable materials more efficiently and may connect designers, manufacturers, and customers through digital or collaborative platforms.	Can support distributed production, reduced logistics, better use of local resources, and lower material waste.

Table 10 — Circular business models and strategies

4.4.1 Choosing the right model for an SME

Not every circular business model is suitable for every SME. Learners should evaluate models according to product type, customer segment, investment capacity, repair skills, logistics capacity, and expected circular benefit.

Selection criterion	Guiding question	Scoring approach
Technical feasibility	Can the product be repaired, refurbished, or taken back without excessive difficulty?	0 = difficult; 3 = easy
Market demand	Will customers value this circular offer?	0 = unclear; 3 = strong demand
Operational capacity	Does the SME have the skills, tools, and space to implement it?	0 = not available; 3 = already available
Financial viability	Can the model create revenue or reduce costs?	0 = weak; 3 = strong
Circular benefit	Does the model keep products/materials in use longer?	0 = limited; 3 = significant

Table 11 — Simple model selection criteria

4.5 WBL application and prototype development

Work-Based Learning is a core component of this module. Learners move beyond theoretical understanding and apply circular economy principles in real or simulated workplace environments. Through this approach, learners engage directly with furniture SMEs, training laboratories, artisan workshops, or case-based scenarios, allowing them to develop practical, industry-relevant skills.

Within this module, WBL is implemented through a hands-on, project-based approach. Learners analyse an existing furniture product or process, identify lifecycle inefficiencies, and propose an improved or new product concept that incorporates circular principles such as material efficiency, modularity, repairability, recyclability, and design for disassembly.

Prototype option	Suitable context	Expected output
Physical prototype	SME, training laboratory, or artisan workshop support is available	Small furniture item, component, joint, modular part, or material reuse sample.
Conceptual prototype	Workshop access is limited or the product is complex	Drawings, material specifications, bill of materials, process improvements, and disassembly logic.
Business model prototype	The focus is on commercial circularity or service innovation	Circular Business Model Canvas, take-back plan, refurbishment model, leasing concept, or customer journey.

Table 12 — Prototype options for WBL delivery

4.5.1 WBL process steps

6. Select one existing furniture product, component, or production process from an SME, workshop, or case scenario.
7. Document the current situation: materials, components, production steps, waste points, repair points, and end-of-life barriers.
8. Identify inefficiencies using the indicators from this module: material efficiency, durability, repairability,

disassembly, recyclability, and refurbishment potential.

9. Propose optimization measures and prioritise them according to circular benefit, feasibility, cost, and implementation difficulty.
10. Develop a prototype, prototype concept, or business model prototype that demonstrates the selected improvement.
11. Present the proposal to peers, trainers, and where possible, workplace mentors for feedback.

Trainer tip: If no company product is available, use a classroom object such as a chair, small table, drawer unit, cabinet door, or upholstered stool. The same diagnosis and optimization logic can still be applied.

4.5.2 Prototype validation criteria

Validation area	Question	Evidence
Material efficiency	Does the optimized concept reduce material waste or use material more effectively?	Before/after material use estimate, cutting plan, or offcut reuse explanation.
Repairability	Can common parts be replaced faster or more easily?	Repair sequence, tool list, estimated repair time.
Modularity	Can components be replaced, upgraded, or reconfigured?	Modular diagram, interface description, spare-part logic.
Disassembly	Can the product be separated into components/materials without major damage?	Disassembly sequence and material pathway map.
Business viability	Can the improvement reduce costs, create revenue, or improve competitiveness?	CBMC, simple cost-benefit logic, customer value statement.

Table 13 — Prototype validation criteria

4.6 European best practices and knowledge transfer

To complement the technical and business-oriented components of this module, trainers should integrate best practices from European countries and companies that are more advanced in implementing circular economy principles in the furniture sector. Partners from EU countries involved in the project can provide valuable experience in circular design, sustainable production, advanced manufacturing technologies, and circular business models.

The purpose of including European best practices is not to copy solutions directly, but to help learners understand how circular principles can be translated into operational processes and business models, and then adapted to local SME realities in the Western Balkans.

- Expose learners and SMEs to proven solutions already applied in more mature markets.
- Demonstrate how circular principles are translated into operational processes and business models.
- Facilitate knowledge transfer between EU partners and Western Balkan stakeholders.
- Encourage adaptation of successful models to local market conditions, available resources, and SME capacities.

Best-practice area	What learners should observe	Adaptation question
Design for disassembly and modular systems	How products are designed for repair, upgrade, and material separation	Which product in a local SME could be redesigned with fewer fastener types and replaceable parts?

Furniture-as-a-Service and product-service systems	How ownership, maintenance, and recovery responsibilities are organised	Could this work for offices, hotels, schools, or events in the local market?
Recycled and certified sustainable materials	How material choices support circularity and market trust	Which reclaimed, recycled, or certified materials are locally available and technically suitable?
Take-back and refurbishment systems	How used products are collected, inspected, repaired, and resold	What reverse logistics and inspection steps would a local SME need?
Digital platforms and distributed manufacturing	How digital tools support design sharing, local production, or material efficiency	Can digital drawings, standard parts, or local production networks reduce waste or transport?

Table 14 — Best-practice themes for knowledge transfer

5. Activities and exercises

The following activities are designed for classroom, workshop, and company-based WBL contexts. Trainers may adapt the product example according to local SME availability.

Activity 5.1 — Circular optimization diagnosis

Field	Description
Type	Pair or small group / Company-based WBL task
Duration	60-90 minutes
Learning outcome(s) addressed	LO1, LO2
Materials needed	One furniture product or case description, worksheet, pen, camera/phone if permitted, basic product information.
Expected output / deliverable	Completed optimization diagnosis table and top-three improvement priorities.
Assessment link	Rubric criteria A and B

Table 15 — Circular optimization diagnosis

Instructions

12. Select one furniture product or process to analyse.
13. List the main materials, components, and production steps.
14. Identify at least five inefficiencies related to design, material use, production, repair, or end-of-life.
15. For each inefficiency, explain the circular risk and propose one possible optimization.
16. Prioritise the three most important improvements according to feasibility and circular benefit.

Trainer notes

Encourage learners to be specific. Instead of writing “reduce waste”, they should explain which material, process step, or component creates waste and how it can be improved.

Figure 2. *Local training in Albania;* Note. Photograph by WICA (2026).

Activity 5.2 — Material yield and offcut reuse challenge

Field	Description
Type	Small group / Workshop task
Duration	60 minutes
Learning outcome(s) addressed	LO2, LO3
Materials needed	Simplified cutting list, product dimensions, example board/panel size, calculator, worksheet.
Expected output / deliverable	Short material optimization proposal with offcut reuse idea.
Assessment link	Rubric criteria B and C

Table 16 — Material yield and offcut reuse challenge

Instructions

17. Review the cutting list or simplified material plan provided by the trainer.
18. Identify where offcuts or unused material are likely to appear.
19. Propose at least three actions to improve material efficiency.
20. Suggest one possible reuse for offcuts that cannot be avoided.
21. Present the expected circular benefit of your proposal.

Trainer notes

This activity does not require advanced mathematical optimization. The goal is to help learners think in terms of yield, standardisation, and reuse.

Activity 5.3 — Circular Business Model Canvas for an optimized product

Field	Description
Type	Small group / Classroom or WBL task
Duration	90 minutes

Learning outcome(s) addressed	LO4, LO5, LO6
Materials needed	CBMC worksheet, product or prototype concept, business model examples.
Expected output / deliverable	Completed Circular Business Model Canvas and five-minute presentation.
Assessment link	Rubric criteria D and E

Table 17 — Circular Business Model Canvas for an optimized product

Instructions

22. Choose the optimized product or prototype concept developed in the previous activity.
23. Complete each element of the Circular Business Model Canvas.
24. Select one circular business model that fits the concept: leasing, refurbishment, take-back, modular product, or material efficiency platform.
25. Explain how the model creates customer value and how it retains product or material value.
26. Present the CBMC to the class or workplace mentor and collect feedback.

Trainer notes

Help learners connect technical features with business logic. A modular product should have a related service, spare-part, upgrade, or refurbishment pathway.

Activity 5.4 — Prototype concept and implementation pitch

Field	Description
Type	Small group / Company-based WBL task
Duration	120 minutes or extended assignment
Learning outcome(s) addressed	LO3, LO5, LO6
Materials needed	Product sample or case, drawing tools, material information, CBMC, assessment rubric.
Expected output / deliverable	Prototype concept, technical description, CBMC link, and implementation pitch.
Assessment link	All rubric criteria

Table 18 — Prototype concept and implementation pitch

Instructions

27. Define the circular problem your prototype or proposal addresses.
28. Describe the optimized product, component, process, or business model.
29. Show how the proposal improves material efficiency, repairability, modularity, disassembly, or end-of-life recovery.
30. Prepare a simple implementation plan with required resources, partners, and first steps.
31. Present the proposal to peers, trainers, and where possible, an SME mentor.

Trainer notes

This activity can be delivered as the final module assignment. The prototype may be physical, conceptual, or business-model based depending on available facilities.

6. Assessment criteria

Assessment should focus on the learner's ability to apply circular optimization thinking to practical furniture-sector situations. The assessment should value evidence, feasibility, and clear reasoning rather than abstract theory alone.

Criterion	Linked LO(s)	Competent performance standard
A. Identification of inefficiencies	LO1	Identifies at least five relevant inefficiencies and explains why each creates a circularity problem.
B. Material and process analysis	LO2	Analyses material or process inefficiencies and proposes at least three realistic measures to reduce waste, rework, or unnecessary resource use.
C. Technical optimization proposal	LO3	Proposes technically feasible improvements related to modularity, repairability, disassembly, material efficiency, or workflow.
D. Circular Business Model Canvas	LO4	Completes the CBMC logically and connects technical optimization to value proposition, revenue streams, activities, resources, and partners.
E. Business model evaluation	LO5	Compares at least three circular business model options and selects a suitable option using clear criteria.
F. Prototype or implementation proposal	LO6	Develops a clear prototype concept or optimization proposal with expected circular benefits and realistic implementation steps.

Table 19 — Assessment criteria linked to learning outcomes

Performance level	Descriptor
Excellent	The learner provides a complete, evidence-based, and feasible optimization proposal that integrates technical, circular, and business model dimensions.
Good	The learner identifies relevant issues and proposes practical improvements, with minor gaps in evidence, prioritisation, or business model logic.
Satisfactory	The learner identifies basic circular optimization issues and proposes general improvements, but the proposal needs more detail or feasibility analysis.
Needs improvement	The learner provides limited or vague analysis and does not clearly connect the proposal to circularity, workplace feasibility, or business value.

Table 20 — General performance descriptors

7. Trainer guidance notes

7.1 Preparing the module

- Select one or two furniture products that learners can physically observe or analyse through drawings and bills of materials.
- Prepare simplified examples of cutting lists, material input, offcuts, or process steps.
- Invite workplace mentors or SME representatives to explain real inefficiencies and constraints.
- Prepare printed worksheets for optimization diagnosis, CBMC, prototype planning, and assessment.

7.2 Facilitating WBL activities

Trainers should encourage learners to ground their proposals in real constraints. A proposal is stronger when it explains not only what should change, but also why the change is feasible for an SME. Learners should be encouraged to consider cost, skills, tools, available materials, customer expectations, and implementation difficulty.

Trainer tip: Avoid allowing learners to propose only “ideal” solutions. Ask: Can this be implemented by a small furniture company? What would it cost? Who would do it? What is the first step?

7.3 Common learner difficulties

Difficulty	Trainer response
Learners focus only on recycling	Redirect them toward higher-value loops such as maintenance, repair, reuse, and refurbishment.
Learners propose expensive technologies immediately	Ask them to identify low-cost changes first, such as standardising parts or improving repair access.
Learners confuse efficiency with circularity	Explain that circular optimization includes value retention, product lifetime, and end-of-life planning, not only cost reduction.
Learners create a technical solution without a business model	Use the CBMC to connect the technical improvement to customers, revenue, partners, and operations.
Learners make vague recommendations	Ask for evidence: material, component, process step, estimated time, expected benefit, or implementation step.

Table 21 — Common difficulties and trainer responses

7.4 Adapting the module to different learning settings

Setting	Recommended adaptation
Classroom only	Use a case study, sample product, or simplified bill of materials. Focus on diagnosis, CBMC, and conceptual prototype.
Training laboratory	Add repair, disassembly, material testing, or small physical prototype tasks.
SME workplace	Use an actual product or production process and involve the workplace mentor in feedback.
Artisan workshop	Focus on material reuse, repair, refurbishment, local craft knowledge, and small-batch optimization.
Advanced learners	Add quantitative elements such as waste percentage, material yield, repair time, and simple cost-benefit comparison.

Table 22 — Adaptation options

References and further reading

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Figure reference

Figure 1. Local training in Albania; note. Photograph by WICA (2026).

Figure 2. Local training in Albania; note. Photograph by WICA (2026).

Annex A: Learner worksheet

This worksheet can be printed and used during the WBL activities. Learners may complete it individually, in pairs, or in small groups.

A1. Product or process selected

Question	Learner response
Name of product/process	
Company/workshop/case context	
Main materials/components	
Main production steps	
Main user/customer context	

A2. Circular optimization diagnosis

Inefficiency identified	Where it appears	Circular risk	Possible optimization

A3. Prioritisation matrix

Proposed improvement	Circular benefit (1-3)	Feasibility (1-3)	Cost difficulty (1-3)	Priority

A4. Circular Business Model Canvas summary

CBMC element	Learner notes

Value proposition	
Customer segments	
Customer relationships	
Channels	
Revenue streams	
Key resources	
Key activities	
Key partners	
Cost structure	
Circular value retained	

Annex B: Assessment rubric

Criterion	Excellent (4)	Good (3)	Satisfactory (2)	Needs improvement (1)
A. Inefficiency diagnosis	Identifies specific, well-evidenced inefficiencies across product, material, process, and end-of-life levels.	Identifies relevant inefficiencies with minor gaps in specificity or evidence.	Identifies basic inefficiencies but with limited explanation.	Identifies few or vague inefficiencies.
B. Material/process optimization	Proposes realistic and well-justified measures to reduce waste, rework, or resource use.	Proposes practical measures with some justification.	Proposes general measures but limited feasibility detail.	Measures are unclear, unrealistic, or not linked to waste/resource use.
C. Circular design quality	Strong integration of modularity, repairability, disassembly, and material efficiency.	Good integration of several circular design features.	Some circular features included but weakly connected.	Little evidence of circular design thinking.
D. CBMC logic	Business model is complete, coherent, and clearly connected to technical optimization.	Business model is mostly coherent with minor gaps.	Business model is incomplete or only partly connected to the technical proposal.	Business model is missing or not relevant.
E. Feasibility and implementation	Clear, realistic implementation plan with resources, partners, and first steps.	Implementation plan is realistic but needs more detail.	Implementation plan is general and lacks evidence.	Implementation is unclear or unrealistic.
F. Presentation and communication	Clear, structured, professional, and evidence-based presentation.	Clear presentation with minor weaknesses.	Understandable but incomplete or not well structured.	Difficult to follow or unsupported by evidence.

Table B1 — Module III assessment rubric